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## GLACIAL DEPOSITS OF THE CONTINENTAL TYPE IN ALASKA[1]

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[1] Based upon field work by the senior author in 1911, and by the junior author in 1910 and 1911. This paper was written after the lamented death of the senior author on March 21, 1912, and the junior author assumes full responsibility for all

## INTRODUCTION

The glaciation of the interior of Alaska forms a striking contrast with that of the coast, where the glacial erosion forms predominate, the deposits being largely under water. The interior, between the coast ranges and the Endicott-Rocky Mountain system, where the National Geographic Society's parties made some studies in 1910 and 1911, has extensive glacial deposits of the continental type, similar to those of United States, and previously described in part by Dawson, McConnell, Russell, Hayes, Spurr, Schrader, Mendenhall, Brooks, and many others. From 1867, when Dall[1] first announced the absence of glaciation on the middle and lower Yukon, to 1906, when Brooks[2] summarized the knowledge of glaciation in Alaska, and continuing to the present time, there has been an increasing amount of specific information concerning the glaciation of the interior of Alaska. Most of this material has been gathered by the geologists of the Alaska Division of the U.S. Geological Survey.

In this paper it is proposed merely to call attention to the availability of this information and to emphasize the conditions in one of the large areas of glacial deposits of the continental type—the Upper Copper River valley—where we made our observations in 1910 and 1911. Here one type of deposit derived from the glacial drift, hitherto not described specifically from Alaska—wind-blown loess or eolian silt—occurs in considerable amount, and is still being deposited.

## CONTINENTAL DEPOSITS IN ALASKA

The areas on the coast of Alaska where glacial deposits occur are relatively small—(*a*) 1,600 square miles east of Yakutat Bay, (*b*) 16,000 square miles in the Cook Inlet-Susitna valley region (perhaps to be considered an interior area), and (*c*) smaller areas.

possible errors of interpretation. Professor J. B. Woodworth has been good enough to read and criticize the manuscript.

Read before the Geological Society of America, December 28, 1911.

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[1] *Amer. Journ. Sci.*, Second Series, Vol. XLV (1868), 99.

[2] *Prof. Paper 45, U.S. Geol. Survey* (1906), pp. 244–49.

The areas of continental glacial deposits in the interior are much larger and may be computed from Brooks's map (Fig. 1) as follows: at least (*a*) 15,000 square miles in the Copper River basin, (*b*)

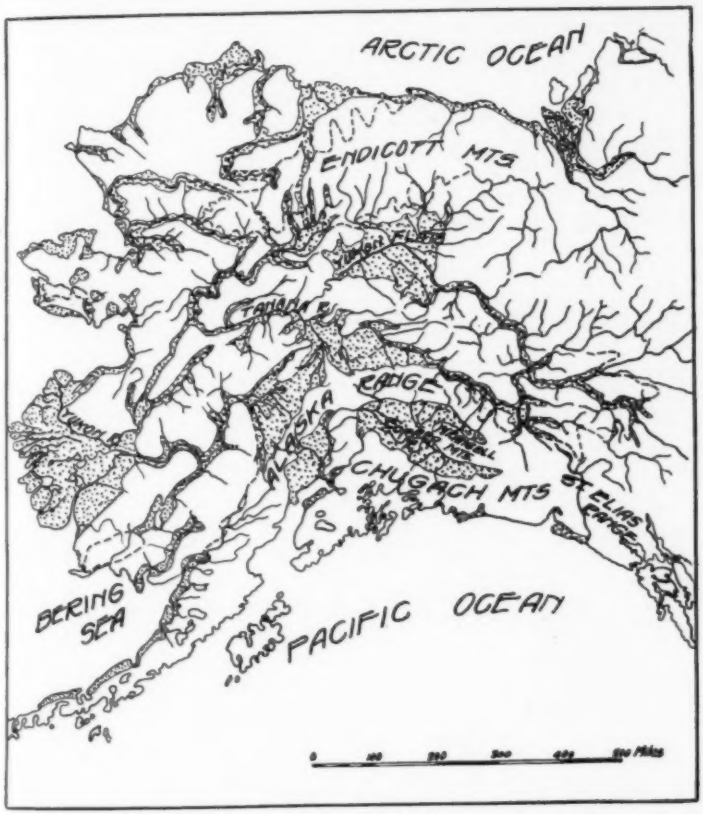


FIG. 1.—Map of Alaska showing areas of glacial deposits of the continental type (dotted areas). Boundaries of glaciation shown by dashed lines. (After A. H. Brooks.)

27,000 square miles in the Tanana and Kuskokwim valleys, (*c*) 17,000 square miles in the Yukon Flats, (*d*) several thousand square miles on the upper Yukon region in Canada, and smaller areas.

The Tanana–Kuskokwim valley area is clearly one of glacial outwash extending far outside the limit of glaciation, as the silt-laden streams from existing glaciers testify. Whether the Yukon Flats area is entirely glacial outwash is not absolutely clear. Russell thought it a flood-plain deposit and Spurr a lake bottom. The narrow strips of Pleistocene silts, sands, and gravels along the rivers, and the broad expanse of the Yukon–Kuskokwim delta have not been specifically considered in this paper, although distant existing glaciers are still supplying much of the sediment even to these regions.

### GLACIAL DEPOSITS OF THE COPPER RIVER BASIN

The upper Copper River flows through an intermontane basin which it shares with the headwaters of the Susitna River. This basin is walled in by the Alaska Range and the Nutzotin, Talkeetna, Wrangell, and Chugach mountains. It is clear that the area of Pleistocene in the upper Copper River valley is wholly of glacial origin. The nature of this intermontane basin is such that practically none of the glacial débris escaped down the stream outlets.

Here the topography and the glacial material have been described in more or less detail by Hayes, Schrader, Mendenhall, Spencer, Moffit, Maddren, Capps, and others,[1] and here the junior author of this paper in 1910 and both of us in 1911 made the observations which form the basis of the present discussion.

*Area covered by drift.*—Throughout over 15,000 square miles (Fig. 1), an area at least equal to the portion of Illinois covered by drift deposits of the last glacial epoch, the basin of the upper Copper and Susitna rivers has glacial deposits which dominate the region.

[1] C. W. Hayes, *Nat. Geog. Mag.*, Vol. IV (1892), 135–36; W. C. Mendenhall, *20th Ann. Rept., U.S. Geol. Survey*, Part VII (1900), 282–84; F. C. Schrader, *ibid.*, pp. 384–86, 410–12; F. C. Schrader, and A. C. Spencer, House Doc. 546, 56th Cong., 2d sess. (1901), pp. 29–30, 58–61, 62–75; Oscar Rohn, *21st Ann. Rept., U.S. Geol. Survey*, Part II (1900), 408–9; W. C. Mendenhall and F. C. Schrader, *Prof. Paper 15, U.S. Geol. Survey* (1903); W. C. Mendenhall, *Prof. Paper 41, U.S. Geol. Survey* (1905), pp. 19–22, 62–74, 79, 88–90; F. H. Moffit and A. G. Maddren, *Bull. 374, U.S. Geol. Survey* (1909), pp. 37–42; S. R. Capps, *Bull. 417, U.S. Geol. Survey* (1910), pp. 36–42; S. R. Capps, *Jour. Geol.*, Vol. XVIII (1910), 38–39; F. H. Moffit and S. R. Capps, *Bull. 448, U.S. Geol. Survey* (1911), pp. 43–52; S. R. Capps, *Jour. Geol.*, Vol. XX (1912), 420–21, 428–30; F. H. Moffit, *Bull. 498, U.S. Geol. Survey* (1912), pp. 39–44, 51–53.

Except near the mountains, no rock outcrops are known. The topography is wholly glacial. The material is till, gravel, sand, silt, clay, and loess.

*Thickness of deposits.*—The observed thickness of the drift is 500–700 feet[1] in places, and may exceed 1,000 feet. This great thickness, in flat plains at a considerable distance from the mountains, forms a striking contrast with the drift of the region south of the Great Lakes, where it rarely exceeds 400 feet in thickness and averages 115 feet in Illinois, as determined by Leverett, and 40 to 250 feet in southeastern Wisconsin, as determined by Alden.

*Plains topography.*—The plains topography dominates the upper Copper River valley, the level of the country rising from 600–800 feet, at the southern edge near the lowest outlet of the basin across the Chugach Mountains, to 3,600 feet near the Alaska Range from which the northern portion of the glacial drift was derived, and 5,000 feet on the slopes of the Wrangell Mountains to the east. The broad area of monotonously even plains is shown along the route traversed in 1898 by Mendenhall, from Cook Inlet to the Alaska Range, a distance of over 100 miles, and our own route across this basin in 1911 from the head of the Copper River canyon at Chitina to the Delta Pass, 160 miles.

Streams have cut deeply (500–800 feet) into the outwash plain, opening out wide valleys, either because of recent uplifts, or, as we think much more probable, because of increased ability to erode because the retreating glaciers have retired into the mountains, are no longer excessively overloaded, and have replaced aggradation by degradation. Within the bordering mountain valleys this degradation results in the leaving of lateral terraces of thick bench gravels.

*Dominance of outwash.*—Outwash gravel, sand, and silt are the chief materials making up the surface of this plain, many of the beds being of alternate weakness and resistance. Lake deposits also make part of the flat topography.

*Till of the normal sort.*—There is also much till of the normal sort, covering large areas and 400–600 feet thick, but in much

[1] W. C. Mendenhall, *Prof. Paper 41, U.S. Geol. Survey* (1905), p. 63; F. H. Moffit and S. R. Capps, *Bull. 448, U.S. Geol. Survey* (1911), p. 49.

of the Copper River basin the till is buried beneath the outwash. Knobs and kettles, and lakes and swamps are abundant in the till areas. Kames and eskers are present, but thus far no one has found drumlins.

*Alternation of beds.*—The alternation of silt and gravel with bowlder clay suggests either a complexity of the period of deglaciation, or else that *pro*-glacial outwash gravels, laid down by glacial streams in front of the advancing ice sheet, are to be identified below the till beds, with *post*-glacial outwash, from the retreating ice, above. Sharply folded structures in the stratified clays and silts show the effects of this overriding. Weathering has not been recognized in the lower beds, so that interglacial epochs are not yet suggested by the Alaskan drift.

*Volcanic complications.*—Near the mountains the presence of lava flows, resting upon, and even intruded in, glacial deposits has been described by Schrader and Spencer,[1] and the complication of past and future ash showers upon the drift is suggested by volcanic ash in some parts of Alaska with thicknesses of a few inches to 75 or 100 feet in an area of many hundred square miles. Present eruptions of Mt. Wrangell, as in April, 1911, show that this process may occur in the future, leaving volcanic ash beds upon or inter-stratified with the till, outwash, and vegetation of the Copper River valley. In at least one locality 35 miles from the nearest active volcano, Mt. Wrangell, enormous masses of angular volcanic rock occur in blocks, buried in the outwash gravels and till beds, suggesting either volcanic showers of large bombs or material carried in glacial floods, as in Iceland. These volcanic fragments are abundantly exposed in 1910 and 1911 in cuts along the newly constructed railway, near Chitina. Other occurrences of the same sort are known, as much as 45 miles from Mt. Wrangell.

*Lake deposits.*—Large areas of very flat topography with clayey soil suggest former, local, glacial lakes, and some of the sections reveal over 300 feet of fine silt with a few scattered stones, perhaps dropped by floating icebergs. In some sections, measured by

[1] F. C. Schrader and A. C. Spencer, House Doc. 546, 56th Cong., 2d sess. (1901), p. 59 and Pl. XI, A, facing p. 54.

Mendenhall, no striated pebbles were found, but other clays with striated pebbles have been observed.

*Sand dunes.*—Overlying the outwash and till, in places, are dunes, and the thickness of the sand is over 20 feet in one case. The cross-bedded sand, in other localities beneath till, gravel, and clay suggests either older sand dunes or cross-bedded outwash, but whether in pro-glacial deposits or in recessional deposits of an earlier oscillation is uncertain. The dunes observed are at the very edges of bluffs and the wind-blown material was derived from the modern outwash plains. Dune sand has been described by Schrader and Spencer,[1] and by Mendenhall,[2] and the authors have observed the same phenomena near the junction of the Copper, Chitina, and Kotsina rivers.

Finer wind-blown material than the dune sand has not previously been observed to our knowledge, except by Schrader and Spencer in 1900. They noted[3] that "besides wind-blown deposits in the forms of dunes, the surface soil is frequently composed of fine sand, doubtless of similar origin, and careful investigation would probably show that eolian deposits are rather generally distributed over the Copper Basin."

### THE LOESS OR EOLIAN SILT[4] OF THE COPPER RIVER BASIN

*Localities.*—The localities where we have observed loess soil or eolian silt are (*a*) at Chitina near the southern edge of the Copper River basin just north of the Chugach Mountains; (*b*) at a number of localities along the military trail between Chitina and the Delta River pass across the Alaska Range, scattered throughout a distance of over 160 miles; and (*c*) near the junction of the

[1] F. C. Schrader and A. C. Spencer, House Doc. 546, 56th Cong., 2d sess., 1901, p. 61.

[2] W. C. Mendenhall, *Prof. Paper 41, U.S. Geol. Survey* (1905), pp. 64–65, 72.

[3] *Op. cit.*, p. 61.

[4] Professor T. C. Chamberlin has suggested that this coarse wind-blown deposit from Alaska be called by some such name as Eolian silt or Loess soil, because of the desirability of retaining the term Loess as a structural term rather than one that is purely genetic, especially as a hard-and-fast genetic classification could not be justified historically and presents insuperable difficulty in such a region as China, the great home of the loess, where fluvial loess and eolian loess are most intimately intermingled.

Tanana and Delta rivers in the interior plateau. The samples described and the pictures shown are chiefly from the first of these localities, where the loess soil was clearly exposed in 1910 and 1911 in the new railway cuts.

*Lithological character.*—Most of the eolian silt or loess is dark brown and made up of fine dust. The color is due to included fragments of vegetation, making the deposit resemble the peaty soil which is also abundant in the region.

Professor B. Shimek, of the University of Iowa, who has been good enough to examine our samples, states[1] that they are not

FIG. 2.—Exposure of loess soil or eolian silt near Chitina, Copper River basin, Alaska, with stump horizons.

exactly physically like the loess of United States, one of them resembling the finest sand which sometimes underlies the loess. This coarseness of the material, which is clearly wind-blown, is what should be expected with the different conditions of loess-accumulation in Alaska and in the Mississippi Valley.

The samples collected in Alaska by the authors have been studied under the microscope by Professor Edward Steidtmann, of the University of Wisconsin. They are made up of particles of various minerals, especially mica, a little feldspar, rare quartz, ferro-magnesian minerals, and some carbonates. There is no

[1] Letter, December 23, 1911.

decomposition of the mineral particles, which are exceedingly angular. Their size varies from .03 to .5 millimeters.

As the loess from the Mississippi Valley averages under 0.0025 to .005 millimeters in diameter,[1] and the maximum size rarely exceeds 0.11 millimeters it is apparent that there must be special reasons why these eolian deposits from the Copper River valley in Alaska are exceptionally coarse. The unusual conditions of deposition of this coarse Alaskan accumulations are explained later (p. 300).

*Topography.*—The topography of this eolian silt is smooth, molded to the underlying bedrock or drift topography, and never dune-like. The exposures show typical steep cliffs, where cut into by streams and by railway grades. There are many vertical joints and the exposure is, therefore, much like those of the loess in the Mississippi Valley and in other localities in the Middle West.

*Thickness of deposits.*—The thickness is from a few feet to 40 or 50 feet, and in one case 80 feet. Some of the deeper cuts do not reach the bottom of the deposit. In a few places the bottom of the loess soil is revealed as a sharp contact with glacial outwash gravel or till.

*Fossils.*—Shells of terrestrial[2] animals are abundant in the exposures, and their presence 20 to 40 feet below the surface and back several feet from the faces of cuts in recent railway excavations is clear evidence that these are the fossils of animals which lived during the period of accumulation of the deposits.

*Vegetation.*—The included vegetation is well-preserved wood in minute fragments and good-sized logs (Fig. 3). There are also upright stumps of trees, up to a foot in diameter and in some of the thicker deposits those are found in layers several feet apart and one above the other. The greatest number of layers of stumps that we have seen was 7, and as these stumps were all clearly in place, it may be assumed that the wind-blown deposit has accumulated during the time necessary for the growth of 7 generations of trees. The present forest upon the loess surface is thick and mature (Fig. 4). Many of the modern trees are 11 to

[1] T. C. Chamberlin and R. D. Salisbury, *6th Ann. Rept., U.S. Geol. Survey* (1885), pp. 279–80.

[2] Collected in 1911 and determined by Professor B. Shimek.

12 inches in diameter. Some of them show 160 rings of annual growth. As there are 7 or more generations of such buried stumps,

FIG. 3.—Five or six generations of stumps buried in loessian deposit near Chitina, Alaska.

this suggests that the region has been deglaciated at least 700 to 1,000 years as a minimum, for during at least this period the eolian deposit has been accumulating.

*Relationships of occurrence.*—Most of the localities where loess soil has thus far been observed in Alaska are upon the edges of bluffs or within a mile or two of the rivers. Here vast quantities of gravel, sand, and fine silt are being transported by the present glacial streams, which have rather steep grades and flow 5 to 7 miles per hour. The grade of the main Copper River, for example, averages 7 to 12 feet to the mile, in contrast with the Mississippi and Ohio whose grades average less than half a foot to the mile. The mean annual rainfall in the Copper River basin is about

FIG. 4.—Mature forest growing upon wind-blown deposit, Copper River basin, Alaska.

36½ inches, only 3 or 4 inches of which come during the summer months when the snow is off the ground. The deposits left by the rivers at low water are, therefore, normally dry and easily blown about by the wind. Severe sand and dust storms are prevalent, indicating the origin of these loessian accumulations in Alaska as wind-blown deposits. We ourselves have witnessed these severe dust storms in 1910 and 1911 and they have been reported by many others from Copper River basin and adjacent regions.[1] Rohn states, for example, that on one occasion in 1899 the material whipped up from the outwash plain "was so thick that it was impos-

[1] Oscar Rohn in *W. R. Abercrombie's Copper River Exploring Expedition, 1899*, Washington, Government Printing Office, 1900, p. 127.

sible to see more than a few rods, and to face it was positively out of the question." Upon the loess-covered surfaces there is, variably, (*a*) thick forest (Fig. 4), (*b*) sparse vegetation, (*c*) grassy slopes, and (*d*) bare soil. Near where the present transportation of the finer material by the wind can still be observed, the grass and trees are notably dusty and there are many dead trees, still standing erect. Doubtless the stumps in the loessian deposits represent trees killed by dust accumulating about their trunks. The preservation of this wood seems to be due to burial in the compact eolian deposit, perhaps in part to the frost, which may also have had something to do with the killing of the trees. The shortness of the stumps seems to come from the fact that the wind blew down the dead tree trunk after it was thoroughly dry, but before it was deeply buried in the loess soil.

The conditions found in the Copper River basin favoring the transportation of dust by the wind and the deposition of eolian silt or loess are: (*a*) abundant water from glaciers, (*b*) much sediment, (*c*) anastomosing branches, (*d*) shrinkage of the streams in the fall and spring when winds are strongest, (*e*) a rather dry climate, and (*f*) dust storms.

In comparison with other areas of similar accumulations the Copper River basin has loessian accumulations as (*a*) terrestrial deposits; (*b*) as in some cases (for example, the Mississippi Valley) associated with glaciation; (*c*) as in some, perhaps all, cases, thickest along rivers; (*d*) coarser than that of the Mississippi Valley. This coarseness may be due to (1) the nearness of the rivers; (2) the violence of the winds here; (3) the coarser sediment carried in the steep-grade streams of Copper River basin as compared with the less steep grade of the Mississippi and its glacial tributaries.

## CONCLUSION

The presence or absence of all these drift deposits seems to be chiefly a matter of favorable topography and drainage. The deposition of the loess or eolian silt seems to be directly related to the glacial outwash, to variations of river volume and water level, to the amount of rainfall, and to the winds. Existing deglaciation in the interior of Alaska is apparently a process much like that formerly in progress in northeastern and central United States.

# THE UNCONFORMITY AT THE BASE OF THE ONONDAGA LIMESTONE IN NEW YORK AND ITS EQUIVALENT WEST OF BUFFALO[1]

EDWARD M. KINDLE

## INTRODUCTION

The importance of stratigraphic breaks has recently been emphasized by a geologist in the following words: "The discovery of such breaks, whether previously suggested by faunal evidence or not, is the most important duty of the progressive stratigrapher."[2] If the demonstration of these breaks is included as a part of the duty of the stratigrapher, most geologists will heartily agree with this sentiment. Stratigraphic breaks not fully supported by evidence have much the same status in geology as have new species which have been discovered but not figured or described. They may or may not be genuine, but in either case they are outside the pale of science until their sponsor has submitted valid evidence of their existence.

The present paper is intended as a contribution to the demonstration and synthetic discussion of a particular unconformity. A stratigraphic break with so great a lateral extent as the one separating the Onondaga and pre-Onondaga sediments merits a more detailed description than it has yet received. The disconformity[3] at the base of the Onondaga limestone, although previously known in western New York[4] and Ontario,[5] has not hitherto been

[1] Published with the permission of the Director of the U.S. Geological Survey and the Director of the Canadian Geological Survey.

[2] *Bull. Geol. Soc. Am.*, XXII (1911), 541.

[3] The term disconformity will be used in the sense proposed by Dr. Grabau (*Science*, N.S., XXIX [1905]) where it is applicable in this paper; but it passes, as will be shown, into a clino-unconformity (Crosby, *Jour. Geol.*, XX [1912], 296) in its western phase. The broader term unconformity is used to include both types of stratigraphic break.

[4] J. M. Clarke, *Memoirs New York State Mus.*, No. 3 (1900), pp. 96–98; A. W. Grabau, *Bull. New York State Mus.*, No. 45 (1901), pp. 117–20.

[5] C. R. Stauffer, *Bull. Geol. Soc. Am.*, (1912), pp. 373–75.

shown to be coextensive with the stratigraphic break at the base of its western equivalents in Ohio and Indiana. It remains to point out the continuity of this break across a wide belt of country extending about 700 miles from eastern New York to the Ohio and Wabash rivers. The Onondaga age of certain sandy beds at the base of the Onondaga limestone in New York which have generally been referred to the Oriskany will also be indicated.

## NEW YORK

*Eastern and central New York.*—The unconformity at the base of the Onondaga though widely extended seems not to have been universal in eastern New York. In southeastern New York there appears to have been no interruption between the Esopus-Schoharie epoch of sedimentation and that of the Onondaga limestone. The fine grits of the former appear, as noted by Van Ingen,[1] to pass very gradually and almost imperceptibly into the impure limestone beds at the base of the latter without any indication of a physical break. There is, too, more resemblance between the fauna of the Onondaga and that of the preceding fine siliceous sediments than could be expected if a physical break had intervened between the periods of their deposition. The presence in the Onondaga of *Anoplotheca acutiplicata*, which is the only common fossil in the Esopus of southeastern New York and adjacent parts of New Jersey, is significant of uninterrupted sedimentation. The failure of many species of the Schoharie to persist into the Onondaga would, of course, be inevitable even with sedimentation uninterrupted, because of the marked difference in the two kinds of sediments and corresponding differences in the conditions under which they were laid down.

While in southeastern New York it appears that the Onondaga limestone sedimentation followed Schoharie sedimentation without interruption of marine conditions, in central and in a portion of eastern New York the evidence is conclusive that the Onondaga limestone was deposited over an extensive area which was submerged shortly before its deposition. Throughout central and western New York there is no trace of the 300 feet of Esopus

[1] *Bull. New York State Mus.*, No. 69, (1903), p. 1204.

and Schoharie formations which, in the Hudson and Delaware valleys, separate the Oriskany from the Onondaga above. In the east-central New York region the Onondaga limestone rests upon an old eroded land surface composed sometimes of the Oriskany sandstone, but much more frequently of limestone of the Helderberg group. The basal beds of the Onondaga if followed westward across New York are seen to rest successively on conformable Schoharie in southeastern New York, disconformable Oriskany sandstone and limestone of the Helderberg group and finally upon Silurian strata in the western part of the state. The physical evidence of the disconformity in this region includes both an irregular or angular contact surface between the Onondaga and subjacent beds and a basal sandstone or conglomerate. The latter is usually less than a foot thick and frequently comprises only a few inches of calcareous sandstone with occasional fragments of limestone from the Helderberg below. This sandy bed at the base of the Onondaga frequently grades upward into the limestone and gradually merges itself into it. The maps and reports which deal with the Devonian in central New York usually refer this basal sandy bed beneath the Onondaga limestone to the Oriskany. There can, however, be but little doubt that it represents reworked Oriskany sand. But it cannot properly be referred to the Oriskany because Oriskany fossils are absent and Onondaga fossils are frequently present in it. This thin basal sandstone band at the base of the Onondaga is well exposed at the Splitrock quarry southwest of Syracuse. At the east end of the Splitrock quarry the 4 or 5 ft. of Onondaga limestone is separated from the Helderberg below by a thin band of sandstone. The lower 2 in. of the sandy beds is probably 75 per cent sand in a calcareous matrix. The percentage of sand decreases and the lime increases upward gradually until all of the sand disappears within 1 ft. of the top of the Helderberg. Only about 6 in. of the sandy band at the base of the Onondaga could properly be called a sandstone and no sharp line of demarkation between this and the slightly less sandy base of the limestone could be drawn. The absence of Oriskany fossils from this basal sandstone and the presence in it of Onondaga corals at the very base of the bed clearly indicate that it belongs

with the Onondaga rather than the Oriskany sediments, as heretofore classed. In places in the eastern part of this quarry the basal bed of the Onondaga includes, in addition to fine sand, flat or oval fragments of the underlying limestone and, more rarely, a rounded pebble of the original Oriskany sandstone. The contact of the sandstone band with the Helderberg is everywhere sharp and clearly defined in marked contrast with the merging contact between the sandy band in the Onondaga above. Sometimes the fine sand penetrates downward into small joints in the Helderberg a short distance. The thin basal sandstone, which I include in the Onondaga formation because of the presence in it of Onondaga fossils, has perhaps its average development at Splitrock. In some areas, however, it is wanting or represented only by a mere film of sand at the contact of the Onondaga and Helderberg. The quarries near Manlius, N.Y., show the minimum development of this sandy band. In some of the Manlius quarries there is no sandstone band at the base of the Onondaga, and fragments of the basal band of this limestone afford no evidence of the presence in them of sand until dissolved in acid, when a small residue of very fine sand is left. The exact line of contact between the Onondaga and Helderberg is easily recognized in the Manlius quarries, where the sandstone is absent, owing to contrast in the appearance of the two limestones. The latter is a fine-textured, hard, dark-blue limestone with few fossils and no crinoid stems, while the Onondaga limestone is a light-gray, coarsely subcrystalline, crinoidal limestone with numerous corals. Some of the corals are of rather large size. One *Favosite* was observed having its base resting on the basal stratum of the Onondaga which has a diameter of 1 ft. Evidence of the disconformity at the contact of these limestones is sometimes distinctly seen in its irregular and angular character, as shown in the photograph (Fig. 1), taken at a quarry one-fourth mile northeast of Manlius. The evenly-bedded Helderberg is here trenched by a shallow troughlike depression about 8 in. in depth, on the side of which the blade of the hammer is seen resting in the photograph (Fig. 1). No trace of residuary clay remains in the Manlius region at the base of the Onondaga, even where eroded depressions like the one shown in Fig. 1 might

be expected to retain it. The Onondaga limestone, however, shows some inclusions in its basal strata of fragments of the Helderberg which were less readily removed by wave action than the subaerial clays which the advancing Onondaga sea must have swept away to other areas. While angular contacts, like the one shown in the figure, are not uncommon, the more usual character of the contact is a horizontal line which affords evidence neither for nor against unconformity with subaerial erosion. It should be pointed out, however, that adjacent disconformable beds, showing no discordance in dip, may have junction over a limited

FIG. 1.—The disconformity between the Onondaga limestone and limestone of the Helderberg group at Manlius, N.Y. The hammer rests on the older formation.

area in a flat plane which represents a considerable amount of subaerial erosion. Even limestones which have experienced the extensive erosion of the present cycle of subaerial degradation in New York may still retain a horizontal upper surface over a limited area. Some of the quarry sections near Manlius, N.Y., show that the contact of the Helderberg and the superposed residuary clay meet along a perfectly horizontal line, although erosion has removed from this particular area many hundreds of feet of rocks.

While the Onondaga limestone rests on the Helderberg, or a thin band of sandstone which, like that at Splitrock, belongs to

the Onondaga over considerable areas in central New York, the Oriskany sandstone is present in many districts. The irregular distribution and great variability in thickness of the Oriskany seem to indicate that the widely scattered patches of the formation represent the remnants of the formation which have been left by the cycle of subaerial erosion which preceded Onondaga deposition. These scattered patches of the Oriskany vary in central New York from 1 ft. or less to 18 or 20 ft.[1] in thickness. The latter thickness

FIG. 2.—Contact of Oriskany sandstone and Onondaga limestone near Jamesville, N.Y. The end of the hammer handle marks the top of the Oriskany and rests upon the etched surfaces of the uppermost band of the Oriskany fossils.

has been reported for the Oriskany on the east side of Skaneateles Lake by Schneider. The contact of the Onondaga and the Oriskany is well exposed in the vicinity of Jamesville, N.Y. In the cliffs near the lake, one-half mile northeast of town, the Oriskany is represented by 30 inches of hard, dark-gray, quartzitic sandstone containing *Spirifer arenosus* and other Oriskany fossils. The

[1] Philip Schneider, *Notes on the Geology of Onondaga County, N.Y.* Syracuse, N.Y.: privately printed, 1894. Pp. 47.

C. C. Wheelock, "The Oriskany Sandstone," *Proc. Onondaga Acad. Sci.*, I (1903). 43.

J. M. Clarke and D. D. Luther, "Geologic Map of the Tully Quadrangle," *Bulletin New York State Mus.*, No. 82 (1905), p. 43.

stratum of the Onondaga limestone immediately above the Oriskany in this section contains a considerable amount of sand, as it does at Splitrock where the Oriskany is absent. The large and numerous Oriskany fossils cease abruptly at a definite plane a little below the top of the arenaceous beds and thus indicate precisely the top of the Oriskany. The sandy element of the basal beds of the Onondaga limestone disappears within from 4 to 10 in. of the top of the Oriskany. The contact of the two formations and the large Oriskany fossils in the lower formation which project beyond the surface of the weathered sandstone are shown in the photograph (Fig. 2). Southwest of Jamesville one-half mile, at the cascade west of the reservoir outlet, the thickness of the Oriskany is about twice that seen in the lake cliffs northeast of town. The section exposed at this point shows:

JAMESVILLE SECTION

| | Ft. |
|---|---|
| Light-gray limestone with corals and other fossils (Onondaga) | 7 |
| Hard dark-colored sandstone cemented with lime and holding Oriskany fossils (Oriskany) | 6 |
| Thin and evenly bedded dark lead-gray limestone (Helderberg) | 15 |

The Onondaga limestone forms the top and the Helderberg the bottom of the fall. The characteristic chert lenses will be noted in the Onondaga limestone above the hammer in the photograph (Fig. 3).

West of the Finger Lake region the disconformity at the base of the Onondaga eliminates from the section not only the Schoharie and Esopus but the Helderberg as well, letting the Onondaga rest in the western part of the state upon rocks of Silurian age.

*Western New York.*—The disconformity which marks the break in sedimentation between the Silurian and Devonian systems in western New York is very plainly indicated by both the physical and the faunal evidence in the vicinity of Buffalo. The contact of the Cobleskill and Onondaga limestones is marked by an irregular line in the Falkirk cement quarries and in many other places in the same region. One of the localities where eroded depressions in the Cobleskill may be seen at the base of the Onondaga is in the rock cut of the Lake Erie & Western R.R. near its intersection

with Main Street in northeast Buffalo. Here the abruptly undulating line of separation between the Onondaga limestone and the subjacent Cobleskill is frequently marked by a band of clay or shale a few inches in thickness. In the quarry of the Buffalo Cement

FIG. 3.—Oriskany sandstone and adjacent beds of the Onondaga limestone and limestone of the Helderberg group southwest of Jamesville, N.Y., ½ mile. Lower end of hammer handle marks the top of the Oriskany. The Helderberg forms the foot of the fall.

Company small caverns appear to have been developed in the Cobleskill during the land interval at the end of Silurian time. These contain sand fillings which have been described by Dr. J. M. Clarke.[1] At the cement quarries near Akron a thin band of blue

[1] *Memoirs New York State Mus.*, No. 3, III (1900), 98.

clay or dark shale generally marks the unconformity. The following section just north of Newmans Akron Cement Works will show the character of the unconformity here.

NEWMANS CEMENT WORKS SECTION

| | Ft. | In. |
|---|---|---|
| *Onondaga*— | | |
| Limestone and black chert | 6 | |
| Gray coralline limestone | 4–5 | |
| Dark coffee-colored calcareous shale | | 2 |
| Corals and dark shale | | 4 |
| *Interformational clay*— | | |
| Bluish gray shale, much like clay, with limestone pebbles | | 1 |
| *Cobleskill*— | | |
| Drab-colored magnesian limestone | 4–6 | |

Fig. 4 shows the highly irregular and uneven character of the eroded surface of the Cobleskill on which the Onondaga was deposited. At the large quarry, 1 mile northwest of Akron, the stripping of the Onondaga limestone down to the top of the Cobleskill has exposed the upper surface of the latter over a surface of several hundred square yards. This shows admirably the irregular hummocky surface which was covered by the sea during the Onondaga submergence. These inequalities in the surface of the Cobleskill rise above the troughs which separate them from 4 to 6 ft. The surface resembles in its irregularity that which may often be seen where the residuary clay has been stripped from a limestone in the process of quarrying.

ONTARIO AND OHIO

The field observations of the writer on the unconformity at the base of the Onondaga limestone include sections in both Ohio and Ontario. But the recent detailed work of Dr. C. R. Stauffer[1] in these areas on the Onondaga and associated beds will make citation of this author's results, together with some supplementary observations of the writer, suffice for this discussion.

*Ontario.*—The Onondaga limestone west of Buffalo rests either on the Oriskany sandstone or the Salina formation where the Oriskany is absent as far west as Springvale, Ontario. To the westward of Springvale the Onondaga lies disconformably on a

[1] *Bull. Geol. Soc. Am.*, XXIII, 371–76.

limestone bed in the upper part of the Monroe formation, to which Scherzer, Grabau, and others have applied the name Anderdon limestone. This bed holds a peculiar fauna of supposed Silurian age.[1]

In Ontario the relationship of the Oriskany sandstone to the Onondaga limestone seems to have been misunderstood until very recently. Collections and lists of fossils made by the earlier students of the Ontario Devonian purporting to represent the Oriskany have shown a large proportion of Onondaga species. This has led to the generally accepted view that a fauna existed in

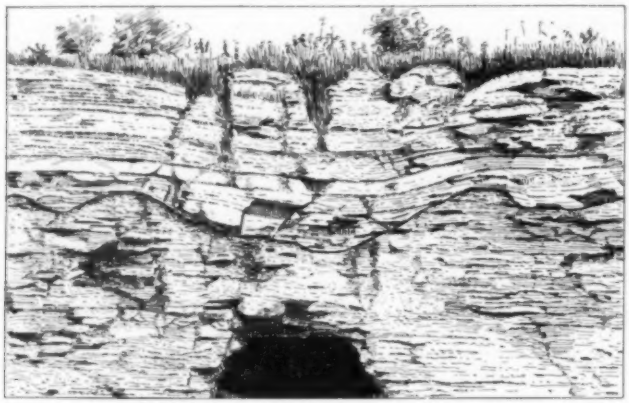


FIG. 4.—The disconformable contact (A–B) of the Onondaga and the Cobleskill limestones at one of the Akron, N.Y., cement mines. From a photograph.

Ontario which was intermediate in character between the ordinary Oriskany and Onondaga faunas. A new formation name—Decewsville formation[2]—was proposed for the beds holding this fauna. Dr. C. R. Stauffer[3] has recently shown that the "Decewsville" fauna of mingled Onondaga and Oriskany affinities has had its origin in the mixing of fossils from adjacent formations. The relationship of Oriskany and Onondaga formations he has found

[1] *Mich. Geol. and Biol. Surv. Pub. 2*, Geol. Ser. (1910), pp. 42–48.

[2] Ulrich and Schuchert, "Paleozoic Seas and Barriers in Eastern North America," *Bulletin New York State Mus.*, No. 52 (1901), p. 653.

[3] *Bull. Geol. Soc. Am.*, XXIII, 371–76.

to be essentially the same in Ontario as it is in New York. The basal beds of the Onondaga are more or less sandy and approach in appearance the Oriskany sandstone below but contain no Oriskany fossils. The Oriskany sandstone is highly irregular both in thickness and in distribution in Ontario as it is in central New York. It is frequently absent from the sections showing the Onondaga limestone. Where it is present it may thin from a thickness of 15 ft. or more to a few inches in a distance of a few rods. This probably results in large part from the Oriskany sandstone filling troughs of erosion in the Salina formation. The accompanying diagram (Fig. 5) shows the relations of the Onondaga limestone and subjacent Oriskany and Salina formations near Decewsville, Ontario. An excavation about 200 ft. northeast of

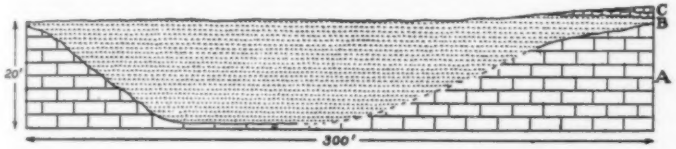


FIG. 5.—Section exposed in vicinity of Oneida Sand Company's quarry, Decewsville, Ont.: A, Salina beds; B, Oriskany sandstone; C, Onondaga limestone.

the Oneida Sand Company's quarry two miles northwest of Decewsville shows the following section:

DECEWSVILLE SECTION

| | |
|---|---|
| Onondaga limestone | 2 ft. |
| Oriskany sandstone | 17 in. |
| Limestone (Salina formation) | 30 ft.+ |

In the quarry less than 200 ft. from the above section the Oriskany sandstone has thickened to nearly 20 ft., as shown in the diagram. Where the Oriskany is absent the Onondaga-Salina contact is doubtless sometimes as irregular as the Oriskany-Salina contact shown in Fig. 5. But the limited number of good exposures and the absence of quarries where the Oriskany is wanting leave the character of the Onondaga-Salina contact to be inferred from the nature of the Oriskany-Salina disconformity. While the physical evidence of the disconformity at the base of the Oriskany

is more striking than that of the stratigraphic break at the base of the Onondaga limestone, evidence of the latter is not wanting. Stauffer[1] states that good-sized pieces of the sandstone containing Oriskany fossils may be found imbedded in the lower part of the cherty limestone, while at other places not far distant the Onondaga rests directly on the Silurian, with only here and there remnants of the Oriskany lying between.

*Ohio.*—The fauna of the Columbus limestone, which has been listed by Stauffer,[2] affords satisfactory evidence that this limestone is the Ohio representative of the Onondaga limestone. The fauna, lithology, and stratigraphic relations of the Columbus limestone together furnish unmistakable evidence of its identity with the Onondaga limestone. The disconformity at the base of the Columbus limestone has been described by Dr. Stauffer as follows:

> The Middle Devonian of Ohio naturally falls into three divisions, of which the lowermost is known as the Delaware limestone and the upper as the Olentangy shale. This division is based on both lithological and faunal differences which in some respects are more apparent in the vicinity of Columbus, although not wanting in any of the belts of outcrop. . . . .
>
> The base of the Columbus limestone rests upon the Monroe formation; this contact being that between the two great systems, the Silurian and the Devonian. There is thus a great time gap or unconformity, between these two formations, which is strikingly illustrated by the decided change in character and abundance of animal remains. In some localities the lowest layers of the Columbus contain an abundant fauna which in many respects resembles that of the upper part of the same formation, but where these lower layers have been observed in Franklin, Delaware, and Union counties, a basal conglomerate is found which consists of large and small water-worn pebbles of the underlying formation imbedded in a matrix of Columbus limestone. Where this conglomerate is developed few fossils are found; probably because the organic remains, which existed in these localities at the time the layers in question were being deposited, were ground to a shapeless mud by the continuous action of the waves among the pebbles of a rocky coast. This conglomerate was formerly supposed to represent the Oriskany sandstone of New York, and was so mapped by the geologists who made the first county reports, as well as by Newberry himself; but, since this basal conglomerate

[1] *Bull. Geol. Soc. Am.*, XXIII (1912), 373.

[2] C. R. Stauffer, "The Middle Devonian of Ohio," *Bull. Ohio Geol. Survey*, No. 10. (1909), pp. 160–70.

is not continuous and has not been proven to be Oriskany, it has been customary of later years, and perhaps wisely, to drop the Oriskany sandstone from the Ohio scale and include these deposits with the Columbus limestone to which they are at least very closely related.

It will be noted in the description of this disconformity in Ohio that it is characterized locally, as in central New York, by a conglomerate. This is particularly well developed in the central Ohio region near Columbus, where according to Dr. Stauffer[1] decided evidence of the erosion period which intervened is found in the well-developed basal conglomerate of the overlying Columbus limestone.

INDIANA

*Ohio valley.*—The Columbus limestone of central Ohio and the Onondaga of New York are represented in southern Indiana by a limestone which bears the closest resemblance to them faunally. This formation has been named in Indiana the Jeffersonville limestone. It is the lowest formation of the Devonian as developed at the Falls of the Ohio. This formation has been shown to hold the same fauna and to be the equivalent in the Ohio valley of the Onondaga limestone of New York.[2] It lies between the Sellersburg limestone and the Louisville limestone of Silurian (Niagaran) age. This formation has perhaps its most typical development at the Falls of the Ohio just below the city of Jeffersonville, where it has a thickness of about 20 ft. It is a light- or bluish-gray crystalline or subcrystalline limestone, occurring both as a massive and as a thinly stratified limestone.

The fossil coral reef for which the Falls of the Ohio have long been noted occurs in the lower part of this formation. The important rôle played by corals in the formation of this limestone is indicated by the great size attained by some individuals. One *Favosite* (*F. hemisphericus?*) which was measured has a breadth of 5 ft. and a height of slightly more than 2 ft. *Spirifer acuminatus*

[1] "The Devonian Section of Ten Mile Creek, Lucas County," *Ohio Nat.*, VIII (1908), 273.

[2] E. M. Kindle. The Devonian and Lower Carboniferous Faunas of Southern Indiana and Central Kentucky, *Bull. Amer. Pal.*, No. 12 (1899); The Devonian Fossils and Stratigraphy of Indiana; *Ind. Dept. Geol. Nat. Res., 25th Ann. Rept*, pp. 229–763, 31 pls., 1901.

and *Spirifer gregarius* are abundant and characteristic fossils of the upper portion of the formation. The lower part of the Jeffersonville limestone, and the Louisville limestone are well exposed in the Bear Grass Creek quarries just east of Louisville, Ky. The section exposed at the west quarry shows:

| LOUISVILLE SECTION | Ft. |
|---|---|
| 1. White to light-gray limestone (Jeffersonville limestone) | 10 |
| 2. Light bluish-gray argillaceous limestone (Louisville limestone) | 35 |

Although all of the sediments and faunas which, in eastern New York, represent the Helderberg group and Oriskany sandstone are missing between the Jeffersonville and the Louisville limestones, evidence of angular unconformity has not been observed in the River sections. Such evidence has been secured a little farther north, however.

North of the Falls of the Ohio 10 or 15 miles, sections which include the Lower Devonian and Niagaran rocks begin to show a thin bed of rather soft, dark-buff to brownish fine-grained magnesian limestone—the Geneva limestone. This formation lies between the Jeffersonville limestone and the Louisville limestone. It thickens gradually toward the north and reaches its maximum development along Flat Rock Creek. The Geneva limestone is generally a massive light-buff to chocolate-brown saccharoidal magnesian limestone. It varies in lithological characters, however. Along Wyloosing Creek, in Jennings County, it is in part a very hard siliceous limestone and was used at one time for mill stones. The fauna of the Geneva limestone indicates that it is of either Schoharie or Onondaga age;[1] probably the former. At the base of the Geneva unmistakable physical evidence of the hiatus between the Geneva and the Louisville limestones has been obtained. An outcrop on the east side of Flat Rock Creek at the ford about 1½ miles above Geneva shows this disconformity. The section exposed at this point is:

| FLAT ROCK CREEK SECTION | Ft. | In. |
|---|---|---|
| 1. Brownish dolomitic saccharoidal limestone (Geneva limestone) | 3 | |
| 2. Hard light-gray limestone (Louisville) | 5 | 6 |
| 3. Blue fossiliferous clay with irregular masses of limestone (Waldron shale) | 5 | |
| 4. Hard gray limestone | | 15 |

[1] E. M. Kindle. *Ind. Dept. Geol. Nat. Res., 25th Ann. Rept.*, pp. 535–58, 1901.

The character of the disconformity between 1 and 2 is shown in the accompanying photograph (Fig. 6). The bed on which the hammer rests is No. 2 of the above section. This disconformity is also seen in the William Avery quarry on the east side of Conn's

FIG. 6.—The disconformity between the Devonian and Silurian limestones on Flatrock Creek, Shelby Co., Ind. The hammer rests upon the top of the Silurian limestone.

Creek about 1 mile below Waldron, where it is marked by a band of residuary clay in the following section:

CONN'S CREEK SECTION

| | Ft. | In. |
|---|---|---|
| 1. Brownish-buff sandy-looking limestone | 2 | 6 |
| 2. Clay | | 1 |
| 3. Blue limestone in 3- to 6-in. layers | 5 | 6 |

Between the area in the Ohio valley in which outcrops of the Devonian limestone are abundant, and the Wabash valley, where they are also common in a limited district, an extensive drift-covered plain intervenes in which but two or three outcrops of Devonian rocks are known.

*Wabash valley.*—The Devonian limestones of the Wabash area are differentiated both faunally and lithologically into two divisions, as in the southern part of the southern Indiana area. These two divisions are correlated respectively with the Sellersburg limestone and the Jeffersonville limestone. The Sellersburg formation of the Wabash area contains a Hamilton fauna. It varies from a bluish-drab limestone breaking with subconchoidal fracture to a dark

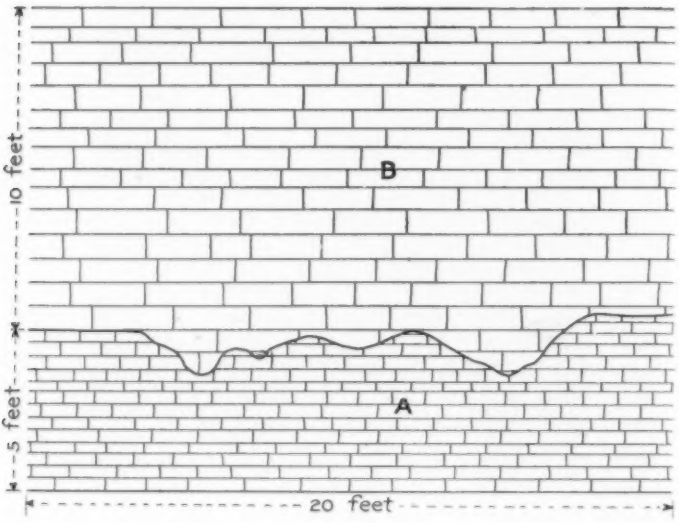


FIG. 7.—Irregular contact line between the Devonian limestone (B) and the Silurian limestone (A) on the bank of the Wabash River, Georgetown, Ind.

argillaceous limestone. *Spirifer pennatus* is the most abundant and generally distributed species.

The formation corresponding to the Jeffersonville limestone at the Falls of the Ohio is a gray crystalline, thin to heavy bedded limestone. This limestone carries a fauna similar to that of the same formation in southern Indiana, and has as one of its most characteristic species *Spirifer acuminatus*. This limestone is unconformable with the Silurian limestone on which it rests. In the other areas in which the stratigraphic break at the base of the Onondaga and its western equivalents has been discussed

there is no discordance in the dip of the strata on the two sides of it, but in the Wabash valley discordance between the Silurian and Devonian limestones is distinctly marked at many outcrops. In this area the term clino-unconformity recently proposed by Professor Crosby[1] is applicable. The Silurian rocks at many points are highly tilted, while the Devonian beds lie nearly horizontal, thus

FIG. 8.—Showing discordance in dip of the Devonian and Silurian limestones at Pipe Creek Falls in northern Indiana.

affording unequivocal evidence of unconformity. Away from the immediate vicinity of the small local domes in the Niagara strata, however, the discordance between the Devonian and Silurian limestones, though slight, can easily be detected with careful observation. Sometimes, however, the discordance is not noticeable.

Just below Georgetown both the Silurian and the Devonian are exposed on each side of the Wabash River. From 5 to 8 ft. of gray crystalline Jeffersonville limestone rests on irregularly eroded Silurian limestone. The line of contact between the two is an

[1] *Jour. Geol.*, XX (1912) 296.

uneven one, frequently rising or sagging on the north side of the river, as shown by the sketch (Fig. 7), but without indicating discordance of dip. On the opposite side of the river the Niagara dips from 6 to 18 degrees to the east, while the Devonian limestone lies horizontal above it, thus indicating deformation as well as erosion previous to the Jeffersonville submergence and showing the relationship of clino-unconformity. The photograph (Fig. 8) indicates this discordance in the dip of the two formations. The Jeffersonville limestone with *Spirifer acuminatus* as its most abundant fossil is the only division of the Devonian here.

The Oriskany sandstone is absent from the Indiana sections. A sandstone known as the Pendleton sandstone resembles it in physical characters, and forms the base of the Devonian section at Pendleton, where it has a thickness of about 7 ft. The fauna of this sandstone, which is wholly unlike the Oriskany, has led to its correlation with the Schoharie grit of New York.

### TIME INTERVAL REPRESENTED

The time interval represented by the hiatus at the base of the Onondaga and its western equivalents varies widely in different parts of the area which has been discussed. In the Wabash valley it marks the break between the Silurian and Devonian systems, while in parts of Ontario and New York a far briefer period within the limits of the Devonian system alone is represented. In the western area the time interval may be stated in terms of missing formations. These include the Salina, at the summit of the Silurian, and at the base of the Devonian the Helderberg limestone and the Oriskany sandstone. In New York and Ontario the relationship of the Onondaga and subjacent beds is of the character designated as a disconformity by Dr. Grabau, the beds showing no discordance of dip on the two sides of the unconformity. In northern Indiana, however, there is in some sections distinct though moderate discordance between the unconformable beds, or clino-unconformity.

The place of the longest time interval represented by the stratigraphic break at the base of the Onondaga and its western equivalents as measured by missing formations coincides with the area

in which discordance of dip exists between the unconformable beds. This is limited to the Cincinnati geanticlinal region of northern Indiana. From this area in the Wabash valley of the maximum length of the stratigraphic break at the base of the Jeffersonville limestone, it decreases more or less regularly eastward by the appearance between the Silurian limestone of Guelph age and the Devonian limestone of Onondaga age of the successively younger formations known respectively as the Salina formation, the Coeskill limestone, the Roundout limestone, the Manlius limestone, and the Oriskany sandstone. With the exception of the last-named formation the western border of each of these lies well to the eastward of the preceding, thus suggesting a shore line retreating eastward during late Silurian and early Devonian time. The distinctive feature of the Oriskany in the New York–Ontario region is its discontinuous character. The western extension to Ontario of Oriskany sediments in irregular patches representing erosion remnants indicates that the easterly retreat of the shore line was reversed about the close of Helderberg time and a submergence of the land occurred in Oriskany time which carried its sediments westward as far as Ontario. Apparently the easterly retreat of the shore line which was reversed with the beginning of Oriskany sedimentation never passed to the eastward of the Hudson River valley in southeastern New York, for no evidence has been found in that region of a stratigraphic break at the base of either the Onondaga or the Oriskany. The disconformity which marks the base of the Onondaga is closely related in space and time with that below the Oriskany.

The erosion of the Oriskany has given it a discontinuous distribution over an area extending from the Hudson River to the middle of southern Ontario. This has resulted in merging the post-Oriskany and pre-Oriskany disconformities into a single disconformity horizon separating the Onondaga and Silurian strata where the Oriskany has been removed.

# SECTIONS OF TWO MICHIGAN SALT WELLS[1]

WILLIAM H. FRY
Bureau of Soils, Washington, D.C.

In connection with recent investigations of American salines by this bureau samples from two wells of the Manistee region of Michigan were obtained through the courtesy of Mr. George Abair, of the Peters Salt Co., East Lake, Mich.

All of the samples examined in the preparation of the sections were obtained by drilling, and consequently many of them were

SECTION OF WELL AT LUDINGTON, MICH. STEARNS SALT & LUMBER CO.

| No. | Depth in Feet | |
|---|---|---|
| 19 | 517– 520 | Calcareous sandstone |
| 20 | 520– 533 | Calcareous and shaly sandstone |
| 21–22 | 533– 573 | Calcareous shale |
| 23–24 | 573– 603 | Calcareous and sandy shale |
| 25 | 603– 608 | Calcareous shale |
| 26 | 608– 609 | Sandy calcareous shale |
| 27 | 609– 615 | Buff calcareous and sandy shale |
| 28–39 | 615– 838 | Calcareous shale |
| 40–60 | 838–1,211 | Sandy calcareous shale |
| 61–69 | 1,211–1,390 | Calcareous shale |
| 70–73 | 1,390–1,463 | Limestone (impure) |
| 74–90 | 1,463–1,801 | Fairly pure limestone |
| 91–97 | 1,801–1,935 | Dolomitic limestone |
| 98–102 | 1,935–2,021 | Calcareous mudstone |
| 103–115 | 2,021–2,281 | Limestone |
| 116 | 2,281–2,290 | Halite |

in a rather finely pulverized condition. In a number of cases, however, fragments large enough for macroscopic examination were present. In such, the specimens were determined primarily by macroscopic methods. In the cases where all of a particular sample was very finely pulverized, the material was mounted in various oils of definite refractive indices and the mineral constituents determined by the ordinary petrographic methods.

[1] Published by permission of the Secretary of Agriculture.

The macroscopic examinations were also checked by this microscopic study. In addition, each sample was subjected to the action of both dilute and concentrated hydrochloric acid, and the character of the effervescence confirmed or modified the previous

SECTION OF WELL 500 FEET FROM EAST LAKE STATION, OF THE PLANT OF THE R. G. PETERS SALT CO.

| No. | Depth in Feet | |
|---|---|---|
| 1 | 593 | Blue calcareous shale |
| 2 | 597 | Calcareous shale |
| 3 | 800 | Calcareous shale |
| 4 | 978 | Limestone |
| 5 | 1,325 | Limestone |
| 6 | 1,400 | Limestone |
| 7 | 1,425 | Limestone |
| 8 | 1,450 | Limestone |
| 9 | 1,475 | Limestone |
| 10 | 1,487 | Calcareous shale |
| 11 | 1,500 | Limestone |
| 12 | 1,595 | Limestone |
| 13 | 1,605 | Limestone |
| 14 | 1,638 | Limestone containing sponge spicules |
| 15 | 1,645 | Calcareous shale containing sponge spicules |
| 16 | 1,650 | Calcareous shale containing sponge spicules |
| 17 | 1,652 | Calcareous shale containing sponge spicules |
| 18 | 1,656 | Calcareous shale |
| 19 | 1,658 | Calcareous shale |
| 20 | 1,661 | Limestone |
| 21 | 1,680 | Limestone |
| 22 | 1,690 | Limestone (rather impure) |
| 23 | 1,700 | Limestone (very sandy) |
| 24 | 1,762 | Limestone (very sandy) |
| 25 | 1,780 | Limestone (very sandy) |
| 26 | 1,800 | Calcareous sandstone |
| 27 | 1,810 | Calcareous sandstone |
| 28 | 1,820 | Limestone |
| 29 | 1,830 | Limestone |
| 30 | 1,850 | Limestone |
| 31 | 1,862 | Limestone |
| 32 | 1,870 | Limestone |
| 33 | 1,880 | Limestone |
| 34 | 1,895 | Limestone |
| 35 | 1,920 | Limestone |
| 36 | 1,930 | Silicious and ferruginous limestone |
| 37 | 1,940 | Silicious and ferruginous limestone |
| 38 | 1,964 | Shaly limestone |

examinations. Difficulty was encountered in determining whether some particular samples, especially the finely pulverized samples, should be referred to the limestone or to the shale group. For example, it was found impossible to say absolutely whether a

particular mount was a calcareous shale or a shaly limestone. But predominance of one or the other of the materials was considered sufficient to place a sample, the less abundant material being considered as an impurity and being indicated by an appropriate adjective. Before coming into the writer's hands, the samples had been subjected to a mechanical analysis and all particles less than 0.005 mm. diameter discarded. The amounts of these very small particles, however, were not large enough to vitiate the accuracy of the determinations.

The sections are given in the accompanying tables.

# THE HURON AND CLEVELAND SHALES OF NORTHERN OHIO[1]

CHARLES S. PROSSER
Ohio State University

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  - Section at Western End of Eagle Cliff Village

CONCLUSIONS

[1] Published by permission of the State Geologist of Ohio.

## INTRODUCTION

Two articles in a recent number of the *American Journal of Science* devoted largely to a consideration of the Ohio shale in northern Ohio[1] appear to make it important that a detailed description of the Huron shale as exposed at its typical locality on the Huron River in northern Ohio be published. This is termed the typical locality because Dr. Newberry stated that "this [Huron] is the shale which forms the banks of the Huron river at Monroeville and below. . . . . The Huron shale in some places contains many concretions of impure limestone, of which hundreds may be seen at Monroeville, where they have washed out of the river banks."[2] Later he wrote: "I have called this in Ohio the Huron shale, because it forms for a long distance the banks of the Huron River, and as it represents several distinct strata in New York and Pennsylvania, it could not with propriety take the name of either of them."[3] Dr. Newberry first published the name Huron shale in 1870 and stated that "its outcrop forms a belt from ten to twenty miles in width, reaching from the Lake shore at the mouth of the Huron River, almost directly south to the mouth of the Scioto."[4]

The area under discussion is shown on the sketch map of Fig. 1 on which the location of the several sections is indicated by an x.

## SECTIONS AND DESCRIPTIONS OF HURON SHALE

### BASAL DEPOSITS

*Slate Cut section.*—The banks of the Huron River from Milan down to its mouth at Huron are composed of glacial and alluvial deposits and the base of the shale is not shown on the river. It is exposed, however, in Slate Cut on the Lake Shore & Michigan Southern Ry. about 4 miles northwest of the Huron River and a

[1] E. O. Ulrich, "The Chattanoogan Series with Special Reference to the Ohio Shale Problem," *American Journal of Science*, 4th ser., XXXIV (August, 1912), 157–83. Edward M. Kindle, "The Stratigraphic Relations of the Devonian Shales of Northern Ohio," *ibid.*, pp. 187–213.

[2] *Geological Survey of Ohio*, II (1874), 189.

[3] *Monograph U.S. Geological Survey*, XVI (1889), 57, 58.

[4] "Report of Progress in 1869 (1870)," *Geological Survey of Ohio*, p. 18, or (1871 ed.) 19.

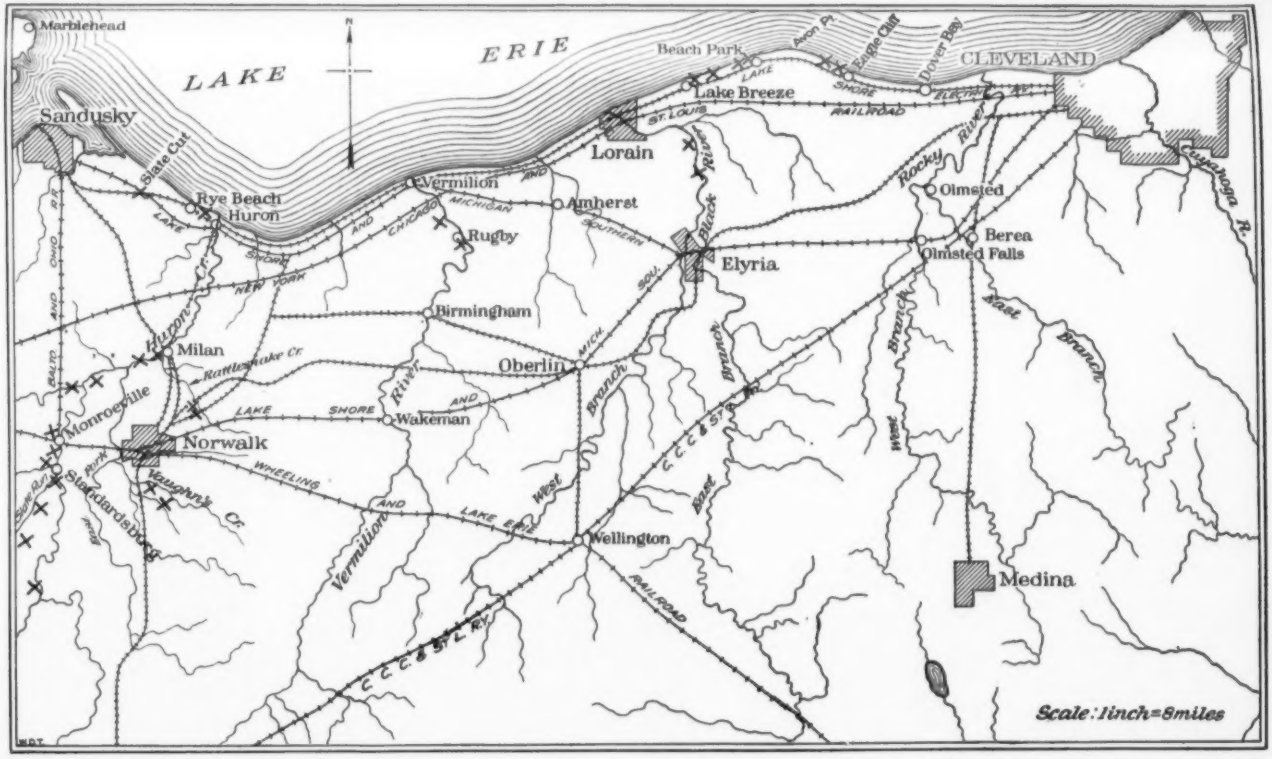


FIG. 1.—Sketch map from Cleveland to the Huron River on which the location of the sections is indicated by the ×-sign

little east of stop 8 on the Lake Shore Electric Ry. The section on the northern bank of the cut is as follows:

| No. | Section of Slate Cut | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 4. | *Huron shale:* Black, bituminous, hard, slaty shale. At one part of the cut is a bluish-gray lens from 2½ in. to 3 in. thick and in the blackish shale just above are Lingulas. Toward the eastern end and some 5 ft. above the base is a spherical concretion. On this bank 8 ft. 3 in.+ are shown and on the southern 9 ft. 6 in. of shale which does not reach the subjacent limestone | 8 | 3+ | 10 | 6− |
| 3. | *Prout limestone:*[1] The upper 1¼ in. contains a large percentage of marcasite, and the entire layer as weathered is greatly ironstained | | 3 | 2 | 2 |
| 2. | Rather shaly layer containing crinoid segments and some other fossils | | 1± | 1 | 11+ |
| 1. | Massive layer of rather dark gray, dense, and very hard limestone. Contains cup corals, crinoid segments, and some other fossils. The calcareous material of the corals has been largely replaced by silica. Dip of top of this layer between 1½° and 2°, 20° S. of E. Bottom of cut | 1 | 10½ | 1 | 10½ |

This section is shown in Fig. 2 and it has been briefly described by Dr. Stauffer who stated that "the Prout member of the Olentangy is nicely exposed with the overlying Huron shale."[2]

*Shore of Lake Erie.*—On the shore of Lake Erie about north of the house of Dr. J. P. Esch and stop 15 of the Lake Shore Electric

[1] This name was proposed for the limestone between the superjacent black Huron shale and the subjacent gray Olentangy shale by the writer in October, 1903, and the name published in December of that year (*Ohio Naturalist*, IV, 47). The typical locality is Deep Cut on the Baltimore & Ohio R.R., 6 miles south of Sandusky and about one mile north of Prout, in which 5 ft. of limestone are now shown (see *Geological Survey of Ohio*, 4th ser., Bulletin 10, pp. 119, 120), although in Dr. Newberry's section, which was probably made when the cut was new, it is given as 10 ft. (see *ibid.*, II (1874), 190, No. 2 of section). This limestone is known only in the northern part of the state and it is probably well to consider it as a lentil or member of the Olentangy formation as has been done by Dr. Stauffer (*ibid.*, Bulletin 10, pp. 117, 119, 120 and Pl. IX).

[2] *Ibid.*, p. 122.

Ry., from 4 to 6 in. of black shale are shown. Some of it is more or less mottled with gray lines and splotches and under water is apparently a light-gray layer. The shale must form the bottom of the lake for some distance out from the shore, and numerous spherical concretions partly covered by water occur. These concretions extend along the lake shore for about one-half mile and are about midway between Huron and Rye Beach. This is the

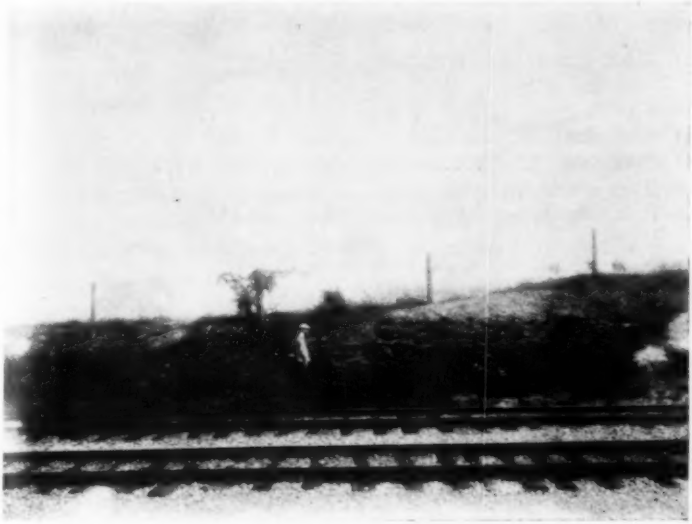

FIG. 2.—Slate Cut showing the upper part of Prout limestone and lower Huron shales. Mr. Roderick stands on top of Prout limestone.

locality where Dr. Kindle, on the authority of Professor E. B. Branson, reports *Dinichthys herzeri* Newb.[1] and which Branson gave as from 50 to 60 ft. above the base of the Huron.[2]

SECTIONS ON THE HURON RIVER

*Milan section.*—The most northern outcrop of Huron shale, as well as the lowest stratigraphically, on the Huron River is on its western bank a short distance south of the river bridge at Milan

[1] *American Journal Science*, 4th ser., XXXIV, 211.

[2] *University of Missouri Bulletin*, Science ser., II, No. 2 (October, 1911), p. 25.

and $7\frac{3}{4}$ miles south of Slate Cut. The entire length of the bank was studied and the following section prepared after such examination. Toward its upper end, the rocks dip steeply upstream so that the lower part of this section is covered. The lower and middle portions show the lower part of the section. All except the lowest part of the following section was measured near the middle of the bend and the lowest portion farther north.

SECTION ABOVE MILAN RIVER BRIDGE

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 13. | Black, bituminous, fissile shale which is slaty before it weathers | 6 | .. | 18 | $10\frac{1}{2}$ |
| 12. | Blue shale, 1 to 2 in | .. | $1\frac{1}{2}\pm$ | 12 | $10\frac{1}{2}$ |
| 11. | Black shale | .. | 4 | 12 | 9 |
| 10. | Blue shale | .. | 1 | 12 | 5 |
| 9. | Black shale | .. | 9 | 12 | 4 |
| 8. | Blue, argillaceous shale containing disk-shaped concretions | 1 | 6 | 11 | 7 |
| 7. | Black, bituminous, fissile shale as weathered which is hard and slaty when freshly exposed. Contains large numbers of spherical, calcareous concretions, an occasional somewhat disk-shaped one, and small marcasite concretions. The spherical concretions range in size from 6 in. to 3 ft. 6 in. vertical measurement and from 9 in. to 4 ft. horizontal. They show beautifully the arching of the shale above the concretion and its depression below, indicating their aggregation after the formation of the shale. Stems of probably *Pseudobornia inornata* (Dawson) White were found at 3 ft. 1 in. and 4 ft. 3 in. below the top of this zone, which is believed to be the one in which Dr. Kindle found the long fragment of a trunk of the above species.[1] Zone varies in thickness from 7 ft. 3 in. to 8 ft. 6 in. | 8± | .. | 10 | |
| 6. | Blue to olive, gritty shale, $2\frac{1}{2}$ to 3 in. | .. | 3 | 2 | 1 |
| 5. | Black shale | .. | $2\frac{1}{2}$ | 1 | 10 |
| 4. | Blue shale, $2\frac{1}{2}$ to 3 in | .. | 3 | 1 | $7\frac{1}{2}$ |
| 3. | Black shale | .. | $3\frac{1}{2}$ | 1 | $4\frac{1}{2}$ |
| 2. | Blue shale, $\frac{3}{4}$ to $2\frac{1}{2}$ in | .. | 2± | 1 | 1 |
| 1. | Black shale to river level | .. | 11 | .. | 11 |

[1] *American Journal Science*, 4th ser., XXXIV, p. 209.

At the lower end of the cliff only the black shale of zone No. 7 is shown where it is 8 ft. 2 in. thick. For some distance farther up the river the rocks rise so that the zones beneath this concretionary black shale are shown; but after passing the bend they dip down again so that at the southern end of the cliff only the upper black shale is shown. A section at this locality is given by Dr. Kindle in which the 9-ft. zone of "fissile black shale with numerous large spherical concretions"[1] obviously corresponds to zone No. 7 of the above section.

*McGue section.*—

SECTION ON THE JAMES MCGUE FARM

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 15. | Bowlder clay and other drift | .. | | | |
| 14. | Blue shale; but entire thickness of zone not shown | .. | 4± | 10+ | .. |
| 13. | Black shale from ½ to ¾ of an in. thick | .. | ½+ | 9 | 9 |
| 12. | Blue shale | .. | 5 | 9 | 8½ |
| 11. | Black shale | .. | 2½ | 9 | 3½ |
| 10. | Blue shale | .. | 2— | 9 | 1 |
| 9. | Black shale | .. | 3¼ | 8 | 11 |
| 8. | Blue shale | .. | 9¼ | 8 | 7¾ |
| 7. | Black shale | 2 | .. | 7 | 10½ |
| 6. | Blue shale; toward the lower end of the bank two somewhat irregular-shaped concretions occur | .. | 11½ | 5 | 10½ |
| 5. | Black shale | .. | 5 | 4 | 11 |
| 4. | Blue shale with an occasional very thin layer of black shale near the center | .. | 6½ | 4 | 6 |
| 3. | Black shale | .. | 3 | 3 | 11½ |
| 2. | Blue shale | .. | 3½ | 3 | 8½ |
| 1. | Black, hard, bituminous, fissile shale which is rather massive and slaty before weathering. Near the top are numerous spherical concretions which were seen only in the upper part of the zone. It also contains marcasite concretions. Two ft. 4 in. are shown where the above section was measured and 3 ft. 5 in. at upper end of cliff, but not reaching the base of the zone | 3 | 5+ | 3 | 5+ |

[1] *Ibid.*, p. 201.

Zone No. 1 of the above section is believed to be the continuation of the black shale at the top of the Milan section (zone No. 13 of that section), but somewhat higher stratigraphically and showing the horizon with spherical concretions which is probably stratigraphically higher than the exposed black shale at the top of the Milan section. Above this zone of rather thick black shale occur alternating zones of blue and black shale which have a considerable total thickness. The next three sections measured in ascending the river, one on the Will Hipteley farm on the eastern side and two on the western side on the Fred Heckelman and Mrs. Helen Andrews farms, do not add very much to the general section of the Huron River; consequently they will be omitted in this article. They are important, however, in tracing the zones shown in the McGue section up the river to the section at Enterprise which will now be described.

*Enterprise section.*—A steep cliff forms the western bank of the Huron River[1] at the former hamlet of Enterprise below the P. J. Schaffer bridge. The bank is difficult to climb but the following section was measured just below the William H. Newton house by Mr. Tom G. Roderick:

SECTION OF WESTERN BANK OF HURON RIVER AT ENTERPRISE

| No. | Thickness | | Total Thickness | |
|---|---|---|---|---|
| | Ft. | In. | Ft. | In. |
| 21. Black, hard, bituminous, fissile shale which projects beyond the lower shales as exposed to the north of the middle of this bank. Thickness estimated as from 5 to 6 ft | 5+ | .. | 60± | |
| 20. Mainly blue, argillaceous shale; but with some layers of black shale from 1 to 3 in. thick. On the high bank on the opposite side of the river, above the Schaffer bridge, disk-shaped concretions occur at about the top of this zone | 32 | 6 | 54 | 9 |
| 19. Black shale | 3 | 4 | 22 | 3 |

[1] One and three-fourths miles above the Milan River bridge are the forks of the Huron River, which are named West Fork and East Fork on the Sandusky quadrangle of the topographic map. The West Fork is the larger, and in accordance with the usage of Dr. Newberry and at least many of the inhabitants of that region the writer considers the West Fork the continuation of the Huron River and so uses it in this article.

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | Ins. | Ft. | Ins. |
| 18. | Blue shale | .. | 11½ | 18 | 11 |
| 17. | Black shale | .. | 10 | 17 | 11½ |
| 16. | Blue shale | 2 | 2 | 17 | 1½ |
| 15. | Black shale | .. | 1½ | 14 | 11½ |
| 14. | Blue shale | .. | 6 | 14 | 10 |
| 13. | Black shale | .. | 1 | 14 | 4 |
| 12. | Blue shale | .. | 4 | 14 | 3 |
| 11. | Black, hard, bituminous, slaty, fissile shale | 2 | 3 | 13 | 11 |
| 10. | Blue shale containing irregular more or less disk-shaped concretions | 1 | .. | 11 | 8 |
| 9. | Black shale | .. | 7 | 10 | 8 |
| 8. | Blue shale | .. | 7 | 10 | 1 |
| 7. | Black shale | .. | 4 | 9 | 6 |
| 6. | Blue shale | .. | 3½ | 9 | 2 |
| 5. | Black, bituminous, hard, slaty, fissile shale containing some large spherical concretions. There are two small ones at almost the top of this zone | 7 | 10½ | 8 | 10½ |
| 4. | Blue, rather argillaceous shale | .. | 8 | 1 | .. |
| 3. | Black shale | .. | 2 | .. | 4 |
| 2. | Blue shale a little farther upstream than the concretions | .. | 2+ | .. | 2 |
| 1. | River level with rather irregular concretions in blue shale | .. | .. | .. | .. |

In the above section the black shale containing spherical concretions of zone No. 5 is believed to be the continuation of the lower black shale containing similar concretions as exposed on the western bank of the Huron River on the Andrews, Heckelman, and McGue farms, and then with the upper black shale of the Milan section. Above this black-shale zone are alternating strata of blue and black shale before reaching a blue-shale zone a foot or more in thickness containing irregular or disk-shaped concretions above which is a conspicuous black-shale zone. This black-shale stratum is 2 ft. 3 in. thick in the Enterprise section, 2 ft. 3 in. in the Andrews, 2 ft. 1½ in. in the Heckelman, and 2 ft. in the McGue section. The section by Dr. Kindle "near the bridge 3 miles southwest of Milan"[1] apparently is at or near the locality where the above section was measured.

[1] *Op. cit.*, p. 201.

Farther up the river near the township line of Oxford Township on the Joe Schlacter farm is another cliff on the western bank of the Huron River showing practically a section of the same portion of the Huron shale as the one just described at Enterprise. Very near the base of the section is an 8-ft. zone of black fissile shale containing spherical concretions, which apparently corresponds to zone No. 5 of the Enterprise section, which is 7 ft. 10½ in. thick. Above this black shale in the Schlacter cliff are alternating strata of blue and black shales with a total thickness of 44 ft., when a zone of black shale capping the cliff is reached, 8 ft. or more of which are shown. The corresponding interval between the two conspicuous zones of black shale in the Enterprise section has a thickness of 43 ft. 10½ in.

*Seymour Creek section.*—The zone of black shale, the lower part of which caps the cliff at Schlacter's and Enterprise, is better shown on Seymour Creek just north of the schoolhouse of Subdistrict No. 6 of Ridgefield Township.

SECTION OF SEYMOUR CREEK NEAR SCHOOLHOUSE NO. 6

| No. | | Thickness Ft. | Total Thickness Ft. |
|---|---|---|---|
| 2. | Black, bituminous, fissile, hard slaty shale. A large globular or spherical concretion is imbedded in this shale, the base of which is about 1½ ft. above the base of this zone. The top of this zone is not shown, but 24½ ft. of the black shale were measured on the bank | 24½+ | 52½ |
| 1. | Blue shale alternating with thin bands of black shale. In the upper part of the blue shale are numerous large concretions which are lenticular or disk-shaped. There are from 8 to 10 in the vicinity of the bend in the creek and one in the stream is 5 ft. 8 in. by 5 ft. 6 in. A twin one on the bank is 11 ft. long by 6 ft. wide. Five+ ft. of this zone are shown at this locality and from its top down to the bridge on the lower road there are shown about 28 ft. of the alternating blue and black shales according to a measurement by Professor J. E. Hyde | 28 | 28 |

This section is shown in Fig. 3, in which the man is indicating with the hammer the contact of the black shale (zone No. 2) which forms the upper part of the bank, and blue shale with thin bands of

black which forms the lower part. Two of the characteristic lenticular-shaped concretions of the soft blue shale are shown a little above water level.

The upper black shale, zone No. 2 of the above section, may be followed up the Huron River to Monroeville, where its top apparently is reached on the bank above the dam and the Main Street bridge; but the writer is not so certain of this identification

FIG. 3.—Black and blue Huron shales on Seymour Creek, the contact indicated by hammer. Spherical concretion in lower part of black shale and lenticular concretions in blue soft shale near water level.

as of that of most of the other zones of this general section. At this locality stems of *Calamites* (*Pseudobornia* [?]) are not infrequent in the black shale of this zone below the Main Street bridge.

*Sections in Monroeville and vicinity.*—There is a shale bank on the northern side of the Huron River between the dam and Stand Pipe and below the Lake Shore Electric Ry. bridge. The bank was measured near the house of Mr. Rivere Needham, where the following section was obtained:

MONROEVILLE SECTION NEAR HOUSE OF RIVERE NEEDHAM

| No. | | Thickness Ft. | Total Thickness Ft. |
|---|---|---|---|
| 9. | Partly covered upper part of bank. Blue and black alternating shales | 8+ | 18½ |
| 8. | Blue shale | ¾ | 10½ |
| 7. | Black shale | ¾ | 9¾ |
| 6. | Dark-blue shale | ⅝ | 9 |
| 5. | Black shale | ¼ | 8⅛ |
| 4. | Dark-blue shale, 3½± in. thick | ¼+ | 7½ |
| 3. | Black shale | ⅛ | 7⅜ |
| 2. | Dark-blue shale | ¼ | 7¼ |
| 1. | Black shale to water level | 7¼ | 7¼ |

On the western side of the Huron River above the Lake Shore & Michigan Southern Ry. bridge in Monroeville is a 10— ft.± bank composed mainly of black shale, but with a little blue shale. The upper part of the bank overlying the black shale shows zones of blue- to olive-colored shale, perhaps 6 in. thick, alternating with black shale. Toward the lower end of the bank are numerous rather irregular to lenticular-shaped concretions a little above river level and a little farther up stream similar concretions occur in its bed. This is apparently the continuation of the lower portion of the Needham section; although its stratigraphic position was not determined as accurately as might be desired. The base of the section is vertically probably not more than 8 ft. above the top of the rocks studied below the dam.

One-fourth mile farther up the river and a little below the house of William Schug is a shale bank from 27 (hand-level) to 30 (barometer) ft. high.

SECTION ON HURON RIVER AT WILLIAM SCHUG'S

| No. | | Thickness Ft. | Total Thickness Ft. |
|---|---|---|---|
| 4. | Black shale near top of bank which is considerably broken | 2+ | 27 |
| 3. | Blue shales alternating with thin layers of black shale, the blue predominating. In the lower part of the blue shales are large lenticular concretions | 19⅞± | 25 |
| 2. | Stratum of massive, black shale | 1⅛ | 5⅛ |
| 1. | Black shale alternating with blue to river level, about 3½ ft. thick | 3½± | 3½ |

The shales in the lower part of this bank are dipping upstream (S. 20° W.) at the rate of between 2° and 4°, so that the nearly 10 ft. of black shale shown on the lower bank above the Lake Shore & Michigan Southern Ry. bridge have been carried beneath water level at this locality.

At the three corners, about 1 mile south of Monroeville, is a road quarry where the following section was measured:

SECTION AT THREE CORNERS SOUTH OF SCHUG'S

| No. | | Thickness Ft. | Total Thickness Ft. |
|---|---|---|---|
| 2. | Continuous hard, slaty, black shale containing *Protosalvinia* (*Sporangites*) | 10⅔ | 16 |
| 1. | Alternating black and blue shales as shown below the quarry | 5⅓ | 5⅓ |

The barometer gave the base of the continuous black shale in the above section as 5 ft. lower than the top of the bank at Schug's. The dip varies from 1½° to 2°, N. 60° E. The continuous black shale, zone No. 2, of this section apparently is the continuation of the broken black shale at the top of the bank in the section below Schug's house.

*Standardsburg sections.*—The hamlet of Standardsburg is located on the Huron River 1½ miles south of Monroeville. The black shale on the western bank of the river a few rods above the highway bridge contains two very large concretions and the following section was measured just below the upper one on the land of Mr. William Cook:

SECTION ON HURON RIVER AT STANDARDSBURG

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 12. | Black, hard slaty shale in which are the two very large spherical concretions. The base of the upper one is only 8 in. above the base of this zone. The vertical diameter of the upper one is about 6 ft. and one-half the distance around it is 17 ft. so that its circumference is about 34 ft. This concretion is shown in Fig. 4 | 5 | 1 | 8 | 8½ |
| 11. | Blue shale which is rather hard | .. | 6½ | 3 | 7½ |
| 10. | Black shale | .. | 5¼ | 3 | 1 |
| 9. | Blue shale | .. | 1¾ | 2 | 7¾ |
| 8. | Black shale in places split by ½-inch layer of blue shale | .. | 2¼ | 2 | 6 |

SECTION ON HURON RIVER AT STANDARDSBURG—*Continued*

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 7. | Blue shale | .. | $10\frac{3}{4}$ | 2 | $3\frac{3}{4}$ |
| 6. | Black shale | .. | $1\frac{3}{4}$ | 1 | 5 |
| 5. | Blue shale | .. | $7\frac{1}{2}$ | 1 | $3\frac{1}{4}$ |
| 4. | Black shale | .. | $2\frac{1}{4}$ | .. | $7\frac{3}{4}$ |
| 3. | Blue shale | .. | $1\frac{1}{2}$ | .. | $5\frac{1}{2}$ |
| 2. | Black shale | .. | 1 | .. | 4 |
| 1. | Blue shale to river level | .. | 3 | .. | 3 |

FIG. 4.—Large, spherical concretion in Huron shale on bank of Huron River at Standardsburg.

Zone No. 12 of the above section evidently corresponds to the lower half of zone No. 2 in the quarry at the three corners to the north of Standardsburg. The spherical concretions in the upper black shale at this locality are the largest that the writer has seen in northern Ohio. The black shales show very clearly that they have been moved from their original position by the formation of the concretions, so that the shales are arched above the concretions and correspondingly pushed down beneath them.

A few rods above the section just described, Slate Run enters Huron River from the southwest and near its mouth the south-

eastern bank is steep and rather high. A section of this bank is as follows:

SECTION OF SLATE RUN AT STANDARDSBURG

| No. | | Thickness | Total Thickness |
|---|---|---|---|
| | | Ft. | Ft. |
| 2. | Apparently all hard, black, slaty shale 22 ft. or more thick. No concretions occur in this bank; but farther up the stream where it is crossed by the north-and-south road there is a large spherical concretion in place in the shale and several occur above the creek level | 22+ | 23 |
| 1. | Top of blue, slaty shale, which corresponds to zone No. 11 of the previous section, about 1 ft. above water level. Blue shale with black shale below to creek level | 1 | 1 |

In the bed of Huron River a short distance east of the mouth of Slate Run are large, somewhat lenticular concretions. On the northern bank of the river at this locality, which is opposite the house of Mr. Charles Burgel, from 15 to 18 ft. of hard, black shale are shown.

SLATE RUN SECTIONS

*Sections near Pontiac.*—On the Huron River to the south of Standardsburg and above the cliff just mentioned, the banks are mainly alluvial and drift. The shales are much better exposed along Slate Run, which is a southwestern tributary of Huron River, and this general section is continued up that run.

The southern bank of Slate Run, at the north-and-south highway bridge and below the railroad at Pontiac, shows 10 ft. of hard, slaty, black shale and below the bridge the bank is higher, apparently showing from 12 to 15 ft. of black shale. The barometer, with an interval of 37 minutes between the readings, gave the level of Slate Run at this bridge as 25 ft. higher than its mouth at Standardsburg. This apparently shows that this black shale is a continuation of the zone forming the greater part of the cliff at the mouth of the run and is probably stratigraphically higher.

Again, where the highway running directly west from Pontiac crosses Slate Run, black shale forms the floor of the stream above the bridge, and below it there is a bank 12 ft. high composed entirely of black shale. The barometer with an interval of 33 minutes between the readings, gave Slate Run as 15 ft. higher than

at the former bridge. This appears to indicate that this zone of hard, slaty, black shale on Slate Run has an approximate thickness of some 50 ft.

*Section on Peter Hay farm.*—Farther south on the farm of Peter Hay on the western side of Slate Run in Sherman Township is a bank composed of alternating black and blue shales which evidently overlies the one of hard, black shale already described along the lower course of this run. The section begins at the northern end of the bank and continues on up stream as follows:

SECTION OF SLATE RUN BANK ON FARM OF PETER HAY

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 12. | Drift and alluvial material containing a considerable amount of worked-over black shale | 8 | .. | 17 | 6– |
| 11. | Black, shattered shale | 1 | 6 | 9 | 5¾ |
| 10. | Zone more or less disturbed but composed of blue and black shale | 2 | 5½ | 7 | 11¾ |
| 9. | Black shale | .. | 8½ | 5 | 6¼ |
| 8. | Blue shale | .. | 8½ | 4 | 9¾ |
| 7. | Black shale | .. | 1¾ | 4 | 1¼ |
| 6. | Blue shale | .. | 3½ | 3 | 11½ |
| 5. | Black, slaty shale | 1 | 4 | 3 | 8 |
| 4. | Blue shale containing very irregular concretions of large size. One of them, very irregularly shaped, is 9 ft. long and lies imbedded in the blue shale; another one is about 7 ft. long | 1 | 3 | 2 | 4 |
| 3. | Black shale, 2½ to 3 in. thick | .. | 3 | 1 | 1 |
| 2. | Blue shale | .. | 4 | .. | 10 |
| 1. | Black, hard shale at northern end in bed of run | .. | 6± | .. | 6 |

In the above section all the blue shale weathers into small pieces. The layers are more or less disturbed and it is difficult to estimate the dip accurately; but near the southern end it is about 2° to the northeast. Farther up the stream the banks in general are low and alluvial and apparently no shales are exposed that are much higher stratigraphically than those on the Peter Hay farm.

### UPPER PART OF HURON RIVER

As already stated, the banks of the Huron River above Standardsburg are generally alluvial and drift. The bed of the river, however, where the east-and-west road west of Macksburg crosses it, is apparently composed of black shale. Again, at the

next bridge to the south crossing the river in the southwestern part of Peru Township and about $1\frac{3}{4}$ miles northeast of Havana, is a bank of slaty, black shale. This bank extends for a short distance on the northern side of the river both above and below the highway bridge and is 10 ft. or so in height. A few rods farther down stream where the river turns to the north is another bank of black, slaty shale on its western side, perhaps a little more than 10 ft. in height. Neither concretions nor layers of cone-in-cone were seen in these banks of black shale. All of the banks farther south on Huron River in Greenfield Township that were visited are composed of alluvial and drift deposits until a point southeast of Steuben is reached where outcrops of Berea sandstone and perhaps Bedford shale occur. Apparently the bank of black shale in the southwestern corner of Peru Township is the last black shale exposed on Huron River and it probably belongs in the Huron.

### GENERAL SECTION ON SLATE RUN AND HURON RIVER

A general section of the shales from the upper bank on Slate Run on the Peter Hay farm down this run and Huron River to the lowest outcrop on the river near Milan has been prepared. The section is as follows and the column on the right indicates the location of each zone:

GENERAL SECTION ON SLATE RUN AND HURON RIVER

| TOTAL THICKNESS | THICKNESS OF ZONE | Location and Description of Zone |
|---|---|---|
| 0′ | 10′ | Black and blue shale of Slate Run on Peter Hay farm. |
| 10′ | 50′± | Black, hard slaty shale on Slate Run. Large spherical concretions in lower part. |
| 60′ | 25′+ | Blue and black shales on Huron River at William Schug's. |
| 85′ | 25′ | Black shale from Monroeville to Seymour Creek. Spherical concretions in lower part. |
| 110′ | 47′ | Blue and black shale in Enterprise section. Irregular lenticular to disk-shaped concretions in upper and lower part. |
| 157′ | 8′ | Black shale near base of Enterprise section. Spherical concretions. |
| 165′ | 3′− | Blue and black shale near Milan. Irregular disk-shaped concretions. |
| 168′ | 8′± | Black shale containing stems of *Pseudobornia*. Spherical concretions. Lower black shale of section near Milan. |
| 176′ | 2′ | Blue and black shale to river level near Milan. Lowest shale outcrop on Huron River. |
| 178′ | | |

Dr. Kindle states:

> The lower part of the black shales above the Olentangy shale is everywhere characterized in Ohio by spherical concretions often of large size. Concretions of this type are entirely unknown in the Cleveland shale both in its typical area and outside of it. On the other hand, in the region where the Cleveland is typically developed the thin limy bands with cone-in-cone structure are common. This type of rock has never been found associated with the spherical concretions. . . . . It is proposed, therefore, to limit the term Huron shale to

FIG. 5.—Huron shale on East Fork of Huron River, below Jacobsburg. Upper part of cliff (15± ft.), all black shale containing spherical concretion near its base with vertical diameter of 5 ft. Blue to bluish-black shale alternating with black from 3¼ in. below base of concretion for 9 ft. to river level.

> those beds of the Ohio shale exposed on the Huron River, at Rye Beach and elsewhere, in which the spherical concretions occur and the Cleveland shale to the higher beds in which they do not occur and in which the cone-in-cone structure does occur.[1]

In northern Ohio the writer has not seen any spherical concretions in the Cleveland shale or cone-in-cone layers in the Huron shale. In central Ohio, however, thin, limy, lenticular layers with

[1] *American Journal of Science*, 4th ser., XXXIV (August, 1912), 198, 199.

cone-in-cone structure occur at least in the lower part of the Ohio shale, as for example in "the Narrows" and other glens north of Worthington. In the general section of Huron River and Slate Run large spherical concretions occur in the lower part of the highest thick zone of black shale as well as in all the lower zones of black shale with a thickness of 8 ft. or more. It appears certain, therefore, that all of the rocks composing this section belong in the Huron shale. This section perhaps does not include the highest black shale seen on the Huron River in the southwestern corner of Peru Township in which nothing was seen to show whether it belongs in the Cleveland or the Huron shale. This general section does not extend to the base of the Huron shale, which is shown in Slate Cut on the Lake Shore & Michigan Southern Ry. some $7\frac{3}{4}$ miles north of the cliff just above Milan, where the lowest outcrops of the Huron shale on Huron River are shown. The general section gives 178 ft. of the Huron shale on Slate Run and Huron River and the thickness of the mostly covered interval from the lowest outcrops of the section to the base of the formation in Slate Cut is not known. If to the 178 ft. of Huron shale in the general section the thickness of the interval to the base of the formation be added, it will certainly give a thickness of over 200 ft. for the Huron shale on the Huron River. Dr. Kindle estimated that "the Huron will have in the Huron section a thickness of probably 100 feet."[1] A thickness of over 200 ft. for the Huron shale is corroborated by the record of the Citizens' Well, No. 1 at Norwalk, about 5 miles east of Monroeville. The well is located by the side of the Wabash R.R. just east of the Norwalk Gas Plant and its mouth is 40 ft. higher than the level of East Fork Huron River at the old waterworks. The first 85 ft. of the well was in drift,[2] and the Prout limestone which directly underlies the Huron shale in this region was reached at a depth of 288 ft. according to the writer's notes. From a study of the outcrops in the vicinity of Norwalk it appears that the black shale struck in this well at a depth of 85 ft. is strati-

[1] *Ibid.*, p. 199.

[2] Dr. Stauffer in his record of this well gives only 76 ft., composed of samples Nos. 1–5, as drift (*Geological Survey of Ohio*, 4th ser., Bulletin 10 [1909], p. 117); but in the writer's notes on an examination of the samples made on September 11, 1905 he gave samples Nos. 1–6 as drift.

graphically below the base of the Cleveland shale and consequently all of the 203 ft. of shale down to the Prout limestone belong in the Huron shale.

## SECTIONS AND DESCRIPTIONS OF CLEVELAND SHALE AND RELATED FORMATIONS

### FROM NORWALK TO BLACK RIVER

*Sections on Vaughn's Creek south of Norwalk.*—As already stated, Dr. Kindle has limited the term Cleveland shale to the higher beds of the Ohio shale in which the spherical concretions "do not occur and in which the cone-in-cone structure does occur."[1] So far as the writer's observations have gone, this appears to be true of the deposits in northern Ohio and he saw no cone-in-cone lenses in the shales on Huron River and Slate Run. The highest outcrops of black shale, however, south and east of Norwalk contain lenses of impure limestone with cone-in-cone structure. The following section on the northern bank of Vaughn's Creek, about 1¾ miles south of the court house in Norwalk and a few rods above the Sandusky, Norwalk & Mansfield trolley bridge, was measured:

SECTION ON VAUGHN'S CREEK SOUTH OF NORWALK

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 18. | Black, hard, slaty shale. Farther up the creek 20+ ft. of this shale are shown with a little cone-in-cone structure | 10± | .. | 25 | 9 |
| 17. | Dark gray shale | .. | 4 | 15 | 9 |
| 16. | Black shale | .. | 6 | 15 | 5 |
| 15. | Blue shale | .. | 8 | 14 | 11 |
| 14. | Black shale | 2 | 2 | 14 | 3 |
| 13. | Blue shale, from 3 to 3¼ in. thick | .. | 3 | 12 | 1 |
| 12. | Layer of cone-in-cone, lens-shaped masses thinning out and reappearing again at the same horizon, from 0 to 2¼ in. thick | .. | 2± | 11 | 10 |
| 11. | Black shale from 5½ to 6 in. thick | .. | 5½+ | 11 | 8 |
| 10. | Gray shale, from 2 to 3 in. thick | .. | 2½+ | 11 | 2½ |
| 9. | Black shale | .. | 3 | 11 | 0 |
| 8. | Gray shale with some thin layers of black from 16 to 18 in. thick | 1 | 5± | 10 | 9 |

[1] *American Journal of Science*, 4th ser., XXXIV, 199.

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 7. | Black shale | .. | 9 | 9 | 4 |
| 6. | Blue, argillaceous shale, from 20¾ to 21 in. thick | 1 | 9— | 8 | 7 |
| 5. | Black shale | .. | 8 | 6 | 10 |
| 4. | Gray to blue shale | .. | 4 | 6 | 2 |
| 3. | Black shale | 5 | 0 | 5 | 10 |
| 2. | Gray shale | .. | 2 | .. | 10 |
| 1. | Black shale to creek level | .. | 8 | .. | 8 |

In the region south and east of Norwalk there is generally a zone of black shale, like No. 18 of the above section, of variable thickness at the top of the Ohio shale, succeeding which, in a few places, is a little of the Bedford shale, but more frequently the Berea sandstone. This irregular thickness of the upper black-shale zone of the Ohio and comparatively little if any of the Bedford formation are due to more extensive erosion before the deposition of the Berea sandstone than occurred in most of Ohio. At part of the localities studied near Norwalk not only is all of the Bedford wanting, but also the upper part of the Ohio or Cleveland shale, so that the Berea sandstone rests on the Huron shale. The writer has described a similar disconformity between the Berea and Bedford formations in central Ohio[1] and in northern Ohio from Rocky River west of Cleveland eastward as far at least as the Grand River Valley,[2] except that the erosion was not so great as in the Norwalk region. There is an example of this disconformity in the immediate vicinity of the section described above. In the bed of Vaughn's Creek and on its northern bank a few rods below the Sandusky, Norwalk & Mansfield trolley bridge is an outcrop of the Berea sandstone at a lower level than the base of the shale section above the bridge. Part of the sandstone is very much contorted with more or less concretionary structure, while some of it is in fairly regular layers. At places there is a bluish, gritty shale below the sandstone and at one point the shale is shown to a depth of 5 ft. and is bluish gray and rather sandy with thin layers of sandstone in it. It is not certain to which formation this shale belongs, although the evidence appears to the

[1] *Journal of Geology*, XX (October—November, 1912), 585–604.

[2] *Geological Survey of Ohio*, 4th ser., Bulletin 15 (1912).

writer to favor its reference to the Berea. Again, a little above the highway and the trolley line, is a knoll a few rods south of the stream, composed of Berea sandstone which shows more or less concretionary structure and ripplemarks. The base of the lowest outcrops in this knoll is 8½ ft. above creek level, while a few rods farther up stream on the opposite bank is the section described above in which the shale runs down into the creek, no sandstone being shown in this section of at least 25¾ ft.

In the various sections studied in the vicinity of Norwalk the writer has regarded the upper zone of black shale of the Ohio, No. 18 of the above section, as the western continuation of the Cleveland shale, or at least as representing part of it. It is perhaps a question at what horizon the line of division between the Cleveland and Huron shales is to be drawn; because if all the shale above the lowest layer of cone-in-cone (zone No. 12 in this section) is to be included in the Cleveland, then its lower part will contain some layers of gray to blue shale. If the base of the lowest layer of cone-in-cone in the above section be considered the base of the Cleveland, then it will extend 4 ft. 1 in. below the base of the upper thick zone of black shale.

Farther up the stream, on its northern (eastern) bank and a few rods below the old Cole quarry, the following section was measured. The old quarry is below the highway passing the J. A. Miller house.

SECTION ON VAUGHN'S CREEK BELOW THE COLE QUARRY

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 11. | Black, hard, slaty shale | 18± | .. | 24 | 5 |
| 10. | Blue shale | .. | 1½ | 6 | 5 |
| 9. | Black shale | 1 | 0 | 6 | 3½ |
| 8. | Black shale but much softer than most of it | .. | 11 | 5 | 3½ |
| 7. | Black shale | 2 | 6 | 4 | 4½ |
| 6. | Blue shale | .. | 3½ | 1 | 10½ |
| 5. | Lenticular layer of cone-in-cone varying in thickness from 0 to 3 in | .. | 2± | 1 | 7 |
| 4. | Black shale | .. | 6½ | 1 | 5¼ |
| 3. | Blue shale | .. | 2¾ | .. | 10¾ |
| 2. | Black shale | .. | 3 | .. | 8 |
| 1. | Blue shale to creek level | .. | 5 | .. | 5 |

At the upper end of the above section the shales are dipping down stream; but farther down where the high bank of upper black shale occurs they are nearly horizontal. In the above section the base of the lowest cone-in-cone layer (zone No. 5) is 5 ft. below the base of the thick zone of black shale at the top as compared with the 4 ft. 1 in. in the lower section. This bank is apparently the one that Read referred to as some 15 or 20 rods directly north of the Cole quarry, the black shale "in position at the same level [as the quarry]; the strata horizontal and undisturbed."[1] The old quarry was in the Berea sandstone and is apparently another locality on this stream showing channel filling.

*Sections on Rattlesnake Creek near East Norwalk.*—On Rattlesnake Creek near East Norwalk, about 3 miles northeast of the courthouse in Norwalk, is an excellent section. It is on the eastern bank of the stream a few rods above the Cleveland, Southwestern & Columbus Ry. bridge and the house of Mr. Peter Shoon (spelled Spohn on his mail box). There is a marked anticlinal fold and the following section was measured near the center of the curve in the bank:

SECTION ON RATTLESNAKE CREEK NEAR EAST NORWALK

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 12. | Hard, slaty, black shale | 17± | .. | 54 | 5 |
| 11. | Soft, olive to blue, argillaceous shale | 2 | 2 | 37 | 5 |
| 10. | This is probably mostly blackish shale, but not so hard as the upper zone | 7± | 0 | 35 | 3 |
| 9. | Mainly soft argillaceous, blackish shale but at base hard, black shale | 5 | 0 | 28 | 3 |
| 8. | Bluish-gray layer, 3 in. or less in thickness, with rather poor cone-in-cone structure. Higher on the bank is another cone-in-cone layer, but its position in one of the above zones was not determined | .. | 3— | 23 | 3 |
| 7. | Black shale, on the second east bank above this section and about 1½ ft. above the subjacent zone of blue shale, is a more or less concretionary layer of cone-in-cone with a thickness varying from 0 to 3± in | 6 | 0 | 23 | 0 |

[1] *Geological Survey of Ohio*, III (1878), 304.

SECTION ON RATTLESNAKE CREEK NEAR EAST NORWALK—*Continued*

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 6. | Blue, soft, argillaceous shale containing small rusty concretions, and an irregular, lenticular one | 2 | 3 | 17 | 0 |
| 5. | Three thin, blue, concretionary, sandy layers separated by blue shale and weathering to a rusty color | .. | 5± | 14 | 9 |
| 4. | Olive shale | 1 | 6 | 14 | 4 |
| 3. | Black or blackish shale containing a concretionary layer with fairly good cone-in-cone structure. It thins out here and there on the bank but after an interval reappears at the same stratigraphic horizon and varies in thickness from 0 to 1½ in. A thin band of blue shale, 2± in. thick was also noted in this zone of black shale | 12 | 6 | 12 | 10 |
| 2. | Blue shale containing apparently a very thin layer, ¼ in. or so thick, of blue hard rock with a slight tendency to cone-in-cone structure | .. | 4± | .. | 4 |
| 1. | Black shale to bottom of creek. These lower two zones and a considerable part of the overlying 12½-ft. zone of black shale are only shown on the lower part of the bank at the axis of the fold | .. | .. | .. | .. |

In the above section there is a layer of cone-in-cone in the black shale of zone No. 3 and even an imperfect one in the blue shale of zone No. 2; consequently if the layers of cone-in-cone are characteristic of the Cleveland shale, it appears that practically all of the above section is to be referred to that formation. Apparently all of the shale overlying the 2¼-ft. zone of blue shale (No. 6) with a thickness of nearly 37½ ft. ought to be referred to the Cleveland.

Farther up the creek on its western (southern) bank on the Frank Landoll farm the Berea sandstone is shown and the following section was measured:

SECTION ON RATTLESNAKE CREEK ON LANDOLL FARM

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 10. | *Berea sandstone:* Shaly to fairly massive sandstone, but more or less shattered and highly inclined to the west. The sandstone has more or less contorted or concretionary structure and there is also some shale, from 8 to 10 ft. shown. The lower layer is full of marcasite.. | 9± | .. | 46 | 6 |
| 9. | Blue, argillaceous shale lithologically like the Bedford | 2 | 6 | 37 | 6 |
| 8. | Covered interval | 1 | 9± | 35 | 0 |
| 7. | Bluish-gray, argillaceous shale lithologically like the Bedford | 16 | 6 | 33 | 3 |
| 6. | Black, hard shale | 1 | 2± | 16 | 9 |
| 5. | Bluish-gray, argillaceous shale from 1½ to 2½ in. thick | .. | 2± | 15 | 7 |
| 4. | Black, hard shale | 1 | 9 | 15 | 5 |
| 3. | Bluish-gray, argillaceous, blocky shale lithologically like Bedford | 4 | 0± | 13 | 8 |
| 2. | Black, slaty shale lithologically like Cleveland | 2 | 4 | 9 | 8 |
| 1. | Covered to creek level; but on the opposite bank just below the old stone bridge is black, slaty shale regarded as Cleveland, which contains numerous specimens of *Sporangites* | 7 | 4 | 7 | 4 |

In the above section the blue to bluish-gray argillaceous shale of zones 7 and 9 certainly has the lithologic appearance and stratigraphic position of the Bedford. The black shale of zone No. 6 is lithologically like the Cleveland; but below is the 2±-in. layer of bluish-gray shale (zone No. 5), then 1 ft. 9 in. of back shale, (zone No. 4), below which is a 4-ft. zone of bluish-gray shale (No. 3), so that it is somewhat uncertain where the line between the Bedford and Cleveland ought to be drawn. A few rods below the locality of the above section are two abandoned quarries with walls from 30 to 40 ft. high. The barometer indicated that the water level in the first quarry is fully as low as the bed of the creek opposite the section where the base of the Berea sandstone is 37½ ft. above creek level. Mr. Landoll reported that a boring on the bank not far from the above section was all in "slate," no sandstone in it. This is evidently another example of channel filling and others may be seen on the banks of the creek farther up stream.

*Vermilion River sections.*—The next river east of the Huron is the Vermilion, which also has steep banks affording excellent sections. One of the most interesting is on its eastern bank at Rugby (formerly called Manchester and Mill Hollow), in Brownhelm Township, 18 miles northeast of Milan on the Huron River.

SECTION ON VERMILION RIVER AT RUGBY

| No. | | Thickness Ft. | Total Thickness Ft. |
|---|---|---|---|
| 6. | *Bedford formation:* Near the bend of the river the upper part of the bank is composed of red shale with an estimated thickness of 20 ft | 20± | 140 |
| 5. | Buff to gray argillaceous shale with an occasional thin, harder layer. Measured on roadside up the hill west of the river | 10 | 120 |
| 4. | Very hard, gray, fine-grained sandstone which weathers to a brownish color and becomes slightly rotten. Shown in gully on eastern bank just below Bacon Brothers' barn and by highway on western side with a thickness of from 5 to 6 in. Blocks of this sandstone are conspicuous on the steep bank above the Rugby River bridge | ½± | 110 |
| 3. | Light to dark-gray, blue and buff, soft to rather hard argillaceous shale with a 1-ft. layer of thin-bedded, very compact argillaceous limestone which weathers to brown. Fossils occur in these shales the most abundantly at 3 ft. 8 in. above the base of the zone. The description and measurement for this zone are from the outcrops by the highway west of the river, where it is 6 ft. 5 in. thick | 6½± | 109½ |
| 2. | *Cleveland shale:* Black, slaty shale finely shown in river bank above the Rugby bridge. Perhaps there are some lighter-colored layers below the middle of this shale. The bank has that appearance as seen from the opposite side of the river, although it is difficult to be certain. In the gully below the Bacon Brothers' barn there is a covered interval of 13½ ft. from the base of the thin sandstone to the top of the first exposed black shale. From this horizon down to river level at the Rugby bridge is 76⅓ ft. as leveled by Mr. T.G. Roderick, the writer's assistant. If to this be added the additional 7 ft. of black shale to bring it up to the base of the Bedford as shown on the western side it will make it 83⅓ ft. Going up the river there is an anticlinal fold which near the bend brings up blue shale, and there are apparently about 8 ft. more of black shale to be added to the bank at the bridge, making altogether 91⅓ ft. of black shale | 91⅓ | 103+ |
| 1. | *"Erie shale" of Newberry:* Blue shale and thin layers of blue micaceous sandstone, from 2 to 5 in. thick. At bend in river and to river level when water is low | 11¾ | 11¾ |

Dr. Newberry stated in his description of the Erie shale that "toward the west it rapidly thins out and is lost sight of south and west of the Vermilion river.[1]"

Mr. Bacon stated that Mr. Terrell used to hunt for fossil fishes at this locality; that the largest number of specimens came from the bank above the bridge; that the horizon could be easily reached from the river level and would, therefore, be in the lower part of what is called the Cleveland shale in the above section.

A well was drilled on the Indian Fort farm, at the house of Mr. S. J. Leimbach, 1¼ miles south of Rugby, in the summer of 1912. The following data concerning it were furnished by Mr. Leimbach and Mr. Henry Schafer, who drilled it. The sandstone "shell" near the base of the Bedford was struck at a depth of 55 ft. and 7 ft. added to this would give 62 ft. for the depth of the top of the Cleveland shale. The Devonian limestone was reached at 670 ft., above which the driller reported 150 ft. of soft shale. In the well on the F. R. Morse farm, about one-fourth mile north of the Leimbach one, Mr. Schafer stated that there is a streak of bastard limestone 8 to 10 ft. thick about 20 ft. below the top of this soft shale. This hard zone is probably the Prout limestone, in which case the Olentangy shale is 120 ft. thick and 670 ft.–130 ft.+62 ft. leaves 478 ft. for the thickness of the Ohio Shale (Cleveland and Huron shale).

On the western side of the Vermilion River at the Cooper or Miles bridge, a mile below Rugby, is a conspicuous cliff of Cleveland shale. A few rods below the bridge is a gully in which the following section was measured:

SECTION ON VERMILION RIVER BELOW COOPER BRIDGE

| No. | | Thickness | Total Thickness |
|---|---|---|---|
| | | Ft. | Ft. |
| 4. | *Cleveland shale:* This zone forms the conspicuous upper part of the cliff and is composed of black, slaty shale. In the gully, where 55 ft. are shown according to the barometer, all black except a one-half inch streak of soft, gray shale. On the highway up western bank near base of continuous black shale a calcareous, gray, lenticular layer 10 to 12 ft. long and about 2 in. thick with cone-in-cone structure.... | 55± | 87 |

[1] *Geological Survey of Ohio*, I (1873), 163.

SECTION OF VERMILION RIVER BELOW COOPER BRIDGE—*Continued*

| No. | Thickness Ft. | Thickness Total Ft. |
|---|---|---|
| 3. Alternating olive and blue layers of argillaceous shale with black, bituminous shale and thin layers of blue, micaceous sandstone. The light-colored layers of shale predominate | 12½ | 32 |
| 2. Black shale predominates but there are thin bands of light-gray shale with an occasional thin one of blue, micaceous sandstone | 5½ | 19½ |
| 1. Alluvium to river level | 14 | 14 |

In the above section there is no evidence to show that the Cleveland shale extends below the base of the 55 ft. of black shale composing zone No. 4. The subjacent shales and thin sandstones may be referred to the Huron shale or its eastern equivalent, the Chagrin formation.

The following section was measured from outcrops by the highway climbing the eastern bank from the Cooper bridge:

SECTION ON VERMILION RIVER EAST OF COOPER BRIDGE

| No. | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|
| 4. *Bedford formation:* Gray, compact, and very hard sandstone, from 6 to 7 in. thick. Farther up the highway is chocolate-colored, argillaceous shale | .. | 6+ | 55 | 0 |
| 3. Thin-bedded, blue, impure limestone alternating with shales | 1 | 5 | 54 | 6 |
| 2. Blue, argillaceous shale in upper part of zone; lower part composed of gray to drab, argillaceous shale | 3 | 1 | 53 | 1 |
| 1. *Cleveland shale:* Black, slaty shale containing two layers with cone-in-cone structure. The upper one is about 1 in. thick and may be traced for some distance in the shale. Considerably lower and near the base of the outcrop is the other one that is a lens of dark-gray, calcareous rock 8 ft. 10 in. long and near the center 4 in. thick, in which the cone-in-cone structure is well shown. The dip along the highway varies from 4° to 10° N. 40° W. Base of black shale not shown | 50± | .. | 50 | .. |

*Black River sections.*—To the east of Vermilion River is Black River, which is also bordered by high banks for much of its course northward from Elyria. On the eastern bank of Black River on the farm of the late Mary L. Demeiner (formerly known as the D. W. Garfield farm) in the extreme southern part of Sheffield Township, $3\frac{3}{4}$ miles north of Elyria and $11\frac{3}{4}$ miles northeast of the Rugby section on Vermilion River, is a steep cliff where the following section was measured. Its upper part is exposed by the northern side of the east-and-west highway a few rods below the Demeiner house.

SECTION ON BLACK RIVER ON DEMEINER FARM

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 5. | *Bedford formation:* Soft, rather light-gray, argillaceous shale, 4 to 5 in. shown | .. | $4\frac{1}{2}\pm$ | 71 | 7 |
| 4. | Dark-gray to blue, rather blocky shales containing the usual Bedford fauna. The fossils are most abundant in the upper part of the zone and *Parallelodon hamiltoniae* (Hall) is the most common species | 1 | $9\frac{1}{2}$ | 71 | $2\frac{1}{2}$ |
| 3. | Soft, light-gray, argillaceous shale from 17 to 18 in. thick | 1 | 6 | 69 | 5 |
| 2. | Coarse, blocky, dark-gray to blackish, arenaceous shale containing some fossils, as *Spirifer* sp. and *Productus* sp. | .. | 11 | 67 | 11 |
| 1. | *Cleveland shale:* Slaty shale, apparently all black. From river level to base of Bedford 60 ft. by barometer and 67 ft. as leveled by Mr. Charles S. Mead | 67 | .. | 67 | .. |

The 67 ft. of black shale in the above section all belong in the Cleveland and the base of the cliff apparently does not reach the top of the Huron or Chagrin shale.

There are steep banks composed mainly of black shale on the sides of the big bend in the Black River east of South Lorain. On the northern side at the "gap" about $1\frac{1}{2}$ miles north of the Demeiner section the bank and outcrops on the highway are apparently all black shale and almost at the base is a calcareous lens $1\frac{1}{2}$ inches thick at the middle, with cone-in-cone structure. These shales contain immense numbers of *Sporangites* which may be collected

in the weathered, loose shales at the foot of the cliff. In the summer of 1912, when this locality was last visited, the river was high so that one could not follow along its lower bank. When it was visited in 1903 it was noted that the western bank shows several small anticlinal and synclinal folds. At a point about opposite the street running west there are 53 ft. of black, slaty shale, apparently all Cleveland, capped by 4 ft. of drift. At the northern end of the cliff near the base it was stated that two layers of micaceous sandstone are brought up, and above these in black shale are at least two bands of soft, olive, argillaceous shale from 2 to 3 in. thick. The lower olive band is about 6 ft. above the upper sandstone stratum. These bands of olive shale are stratigraphically below the base of the 53-ft. bank of black shale and at the northern end of the cliff perhaps 10 ft. of shale stratigraphically lower than the 53-ft. bank are shown.

### SHORE OF LAKE ERIE FROM LAKE BREEZE HOUSE TO EAGLE CLIFF VILLAGE

*Section near Lake Breeze House.*—The lake shore east of the mouth of Black River for nearly 4 miles is said to be composed of drift and soil. Below the grounds of the old Lake Breeze House shales and sandstones appear and the lake shore from this locality eastward is called "iron-bound," on account of the general presence of rock cliffs. The following section was measured on the cliff east of the Lake Breeze House grounds and below the brick schoolhouse in Sheffield Township:

SECTION EAST OF LAKE BREEZE HOUSE

| | Thickness | | Total Thickness | |
|---|---|---|---|---|
| | Ft. | In. | Ft. | In. |
| 14. Bowlder clay to top of cliff | 10± | .. | 15 | 3 |
| 13. Black, bituminous shale which on weathering splits up into thin laminae; the edges are rusty with efflorescence of sulphate of iron (melanterite, $FeSO_4 \cdot 7(H_2O)$) | 2 | 10 | 5 | 3 |
| 12. Soft, gray, argillaceous shale | .. | 1 | 2 | 5 |
| 11. Blue, hard, sandy shale | .. | 1+ | 2 | 4 |
| 10. Soft, gray shale | .. | 1− | 2 | 3 |
| 9. Blue, compact, very fine-grained sandstone, from 4 to 5 in. thick. Fossil fish in black shale below this sandstone | .. | 4½ | 2 | 2 |

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 8. | Black shale from $2\frac{1}{2}$ to $3\frac{1}{2}$ in. thick | .. | 3 | 1 | $9\frac{1}{2}$ |
| 7. | Soft, gray, argillaceous shale containing two thin layers of black shale | .. | 3 | 1 | $6\frac{1}{2}$ |
| 6. | Black shale | .. | $1\frac{1}{2}$ | 1 | $3\frac{1}{2}$ |
| 5. | Thin layer of bluish sandstone | .. | $\frac{3}{4}$ | 1 | 2 |
| 4. | Black shale | .. | $8\frac{1}{2}$ | 1 | $1\frac{1}{4}$ |
| 3. | Gray, argillaceous shale | .. | $1\frac{1}{4}$ | .. | $4\frac{3}{4}$ |
| 2. | Black shale | .. | $2\frac{1}{2}$ | .. | $3\frac{1}{2}$ |
| 1. | Blue to gray, argillaceous shale and base of shale exposed on lake bank | .. | 1 | .. | 1 |

Judging from those studied farther east, all of the shales in the above section are below the base of the Cleveland, with the possible exception of the black shale of zone No. 13.

Mr. Charles Maddock, who lives just west of the Lake Breeze House and formerly collected specimens of fossil fish with the late Mr. Jay Terrell at this locality, said that most of the specimens came from the black shale below the thin sandstone layer of zone No. 9. This indicates that those specimens reported by Mr. Terrell from the lake shore near the Lake Breeze House came from the upper part of the Huron shale which farther east is equivalent, stratigraphically, to the upper part of the Chagrin formation.

Dr. Newberry at first referred these fish-bearing shales to the Huron and stated that:

> the most interesting specimens found in this locality have rewarded the laborious and intelligent search of Mr. J. Terrell, the proprietor of the Lake Breeze House, situated in the immediate vicinity of the outcrop of the fish-bearing stratum.[1] . . . . These specimens we owe to the enthusiasm and intelligence of Mr. Jay Terrell, who found them at his home in Sheffield, Lorain Co. Here the upper portion of the Huron shale forms, along the Lake Shore, cliffs, which are being constantly worn away by the waves. These cliffs have been Mr. Terrell's favorite hunting ground, and as the erosion of the surface revealed here and there the projecting point of a bone, each indication has been followed up with care, and the bone taken out.[2] . . . . The large number of specimens since obtained, and, indeed, all the remains of *Dinichthys* hitherto taken from the summit of the Huron shale at Sheffield, belong, as we now know, to this species [*D. terrelli*], which is quite distinct from that found at the base of the formation at Delaware [*D. herzeri*].[3]

[1] *Geological Survey of Ohio*, II (1874), 214, also see I (1873), 157.

[2] *Ibid.*, II, Pt. II, Palæontology (1875), 3.

[3] *Ibid.*, p. 4.

Later, Dr. Newberry changed his opinion concerning the age of these fish-bearing shales and wrote as follows:

> This dip misled us, and the thinning of the Erie shale, bringing the Cleveland down near to the Huron, caused these two to be confounded, and led to the supposition that the fish-bearing black shales which form the lake shore in Lorain County were the upper part of the Huron; hence all the great Placoderms discovered by Mr. Terrell were at first referred to that formation. This matter was, however, cleared up by an excursion made by the writer westward from Cleveland in 1886, and it is now definitely established that all the outcrops of black shale in Cuyahoga and Lorain Counties belong to the Cleveland shale, and that none of the fossil fishes described from northern Ohio should be credited to the Huron.[1]

*Section on Aaron Hill farm.*—The following section was measured at a little gully on the Aaron Hill farm a few rods east of the end of the Harris road and one mile northeast of the Lake Breeze House:

LAKE SHORE SECTION ON THE AARON HILL FARM

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 11. | Bowlder clay with soil at top | 5 | .. | 18 | 8½ |
| 10. | All black, slaty, bituminous shale. In the shale a lens of coal 1¾ in. thick, 3 ft. long, and 3½ ft. above the sandstone layer of zone No. 6 | 11 | 5 | 13 | 8½ |
| 9. | Blue, argillaceous shale from 1 to 1¾ in. thick | .. | 1½± | 2 | 3½ |
| 8. | Sandstone layer from 0 to 1¼ in. thick | .. | 1± | 2 | 2 |
| 7. | Blue to gray, argillaceous shale | .. | 1½ | 2 | 1 |
| 6. | Blue, compact, micaceous, laminated sandstone layer, from 3 to 6 in. thick, which is the conspicuous one on this part of the lake shore | .. | 4½± | 1 | 11½ |
| 5. | Black shale from 4 to 5 in. thick | .. | 4½± | 1 | 7 |
| 4. | Soft, gray shale from 2 to 3 in. thick with a streak of black shale at the middle of the zone from ¼ to ½ in. thick | .. | 2½± | 1 | 2½ |
| 3. | Black shale | .. | 5 | 1 | 0 |
| 2. | Bluish-gray argillaceous and arenaceous shale | .. | 1 | .. | 7 |
| 1. | Black shale to lake level | .. | 6 | .. | 6 |

The above section is about north of the Aaron Hill farmhouse, and a little farther east than opposite his barn the sandstone layer of zone No. 6 is at lake level. This is a dip of 1½ ft. in a horizontal distance of 375 ft. The sandstone reappears in the cliff

[1] *Monograph U.S. Geological Survey*, XVI (1889), 127.

a little farther east than opposite the first farmhouse east of the Hill's. This shows a small synclinal fold and as the shore is followed eastward to Beach Park and beyond there is seen a succession of small anticlinal and synclinal folds as has been described by Dr. Kindle. He states:

> With few exceptions these structures have very low arches, nearly flat on top, which rise above their troughs from 3 to 8 feet. The width of these gentle undulations usually ranges between 200 and 350 yards, giving an effect not unlike the billowy surface of a subsiding sea. An exceptionally high arch just west of Eagle Point and another at Beach Park rise 20 feet or more. Detailed study of this lake shore section has shown that the east and west limbs of the series of low anticlinal rolls which succeed each other for more than 8 miles are essentially equal, and that for this distance the base of the Cleveland shale shows no westerly declination between Eagle Cliff and Lake Breeze.[1]

The sandstone of zone No. 6 of the above section is an easy one to follow along the lake cliff as long as it is above water or soon reappears in this succession of anticlinal and synclinal folds. It is a blue to bluish-gray, laminated sandstone which splits up into thinner layers, so that it may be called platy, and when it reaches lake level it breaks out in large rectangular slabs. The main line of joints run about 70° W. of N.

*Section on L. B. Ellis farm.*—Another lake-shore section was measured on the L. B. Ellis farm, which is about two miles southwest of Beach Park.

LAKE SHORE SECTION ON THE S. B. ELLIS FARM

| No. | | Thickness | | Total Thickness | |
|---|---|---|---|---|---|
| | | Ft. | In. | Ft. | In. |
| 12. | Black, slaty, bituminous shale. A cone-in-cone lens almost at the base of this zone..... | 6 | 6 | 14 | 4 |
| 11. | Soft, gray and blue, argillaceous shale ..... | .. | 4¾ | 7 | 10 |
| 10. | Black shale..... | .. | ¾ | 7 | 5¼ |
| 9. | Soft, blue to gray, argillaceous shale..... | .. | 3 | 7 | 4½ |
| 8. | Black, bituminous shale..... | .. | ¾ | 7 | 1½ |
| 7. | Soft, blue to gray, argillaceous shale. The total thickness of these gray to blue and black layers of shale between zones 6 and 12 of thick black shale is 12¾ in..... | .. | 3½ | 7 | ¾ |

[1] *American Journal of Science*, 4th ser., XXXIV, 207, 208.

LAKE SHORE SECTION ON THE S. B. ELLIS FARM—*Continued*

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 6. | Black, slaty, bituminous shale with marcasite concretions | 4 | 10 | 6 | $9\frac{1}{4}$ |
| 5. | Soft, blue shale from $3\frac{1}{4}$ to 4 in. thick in which in places near the center of the zone is a little harder material | .. | $3\frac{3}{4}\pm$ | 1 | $11\frac{1}{4}$ |
| 4. | Blue, micaceous, laminated, platy sandstone layer, from 2 to 6 in. thick. Both the top and bottom surfaces appear to be uneven so that the thickness of the layer is variable. The conspicuous sandstone layer with numerous loose blocks along this part of the beach | .. | $4\pm$ | 1 | $7\frac{1}{2}$ |
| 3. | Black shale | .. | $3\frac{1}{2}$ | 1 | $3\frac{1}{2}$ |
| 2. | Soft, blue, argillaceous shale with an inch band of black shale in the center | .. | 5 | 1 | 0 |
| 1. | Black shale to lake level | .. | 7 | .. | 7 |

The $12\frac{3}{4}$-inch zone of gray to blue and black shales between zones 6 and 12 of thick black shale shows the appearance of the gray to blue soft shale at a higher stratigraphic position than in the sections toward the Lake Breeze House. For example, in the section on the Hill farm above the conspicuous sandstone zone are from $2\frac{1}{2}$ to $4\frac{1}{2}$ in. of blue, argillaceous shale and sandstone, and then the 11 ft. 5 in. of black shale extending to the top of the shale outcrop. In this section there are from $3\frac{1}{2}$ to 4 in. of blue shale above the conspicuous sandstone, then 4 ft. 10 in. of black shale overlaid by the $12\frac{3}{4}$ in. of gray to blue and black shale, capped by $6\frac{1}{2}$ ft. of black shale near the base of which is a cone-in-cone layer. This upper zone of black shale, No. 12, certainly appears to belong in the Cleveland.

*Beach Park section.*—In the western part of Beach Park, just west of the bathing beach, a marked anticlinal fold brings up the rocks for some thickness below the conspicuous sandstone layer, which at this locality appears at the top of the bank until it disappears toward the axis of the fold.

LAKE SHORE SECTION IN WESTERN PART OF BEACH PARK

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 6. | Blue, micaceous, laminated, platy sandstone, which is near top of bank, continues on up to the top and is worn away toward the axis of the fold | .. | 6 | 13 | $8\frac{1}{4}$ |
| 5. | Alternating gray to blue, argillaceous and black shale | 6 | 11 | 13 | $2\frac{1}{4}$ |
| 4. | Blue, thin sandstone from $1\frac{1}{4}$ to 2 in. thick | .. | $1\frac{1}{2}\pm$ | 6 | $3\frac{1}{4}$ |
| 3. | Blue to gray and black shale from 6 to 7 in. thick | .. | $6\frac{1}{2}$ | 6 | $1\frac{3}{4}$ |
| 2. | Blue, thin sandstone from $1\frac{1}{2}$ to 3 in. thick | .. | $2\frac{1}{4}\pm$ | 5 | $7\frac{1}{4}$ |
| 1. | Mainly gray to blue, argillaceous shale with some thin layers of black shale. Lenticular layers of clay ironstone occur in these soft shales, which are like those in the Chagrin formation in the western part of Cleveland. Layer of blue, thin sandstone near base of section. Lake level | 5 | 5 | 5 | 5 |

All of the above section closely resembles lithologically the Chagrin formation as shown along the lake shore to the west of Cleveland and Rocky River. A view of the eastern limb of this anticlinal fold to the east of the bathhouse is shown in Fig. 6.

*Avon Point Cliffs.*—The blue, conspicuous sandstone was followed in the cliffs bordering the lake to almost opposite the northern end of the road running south to Avon Center, about one-fourth mile southwest of Avon Point. The writer is uncertain whether this sandstone shows or not in the cliffs at Avon Point; but to the east of Avon Point in Avon Lake it has thinned to a somewhat concretionary layer from a fraction of an inch to 2 in thickness. Two ft. or more below is another thin sandstone and 4 ± ft. below that is a zone of three sandstones separated by 8 or 9 in. of shale. Still lower, not far above lake level, are several thin sandstones and the lower shales contain lenticular ironstone concretions. At this locality there are 10 ft. or more of apparently black Cleveland shale forming the upper part of the cliff, below which are some 15 ft.

of blue to gray shale with thin bands of black shale containing layers of sandstone from 1 to 2 in. thick, all of which is referred to the Chagrin formation. This cliff is at the D. E. Parsons cottage in Avon Lake at stop 50 on the Lake Shore Electric Ry. a few rods east of the brick schoolhouse of Avon District No. 4. It is three-fourths of a mile southeast of Avon Point and about one and one-

FIG. 6.—Cliff of Huron shale=Chagrin at Beach Park on shore of Lake Erie, showing one limb of anticlinal fold.

half miles northwest of the western end of Eagle Cliff. The rocks are dipping easterly; but east of Avon Point they lie much more nearly horizontal than to the west of it where there is so much folding.

*Section opposite house of John Goetz.*—The following section was measured opposite the house of Mr. John Goetz about one mile west of the western end of Eagle Cliff:

LAKE SHORE SECTION OPPOSITE HOUSE OF JOHN GOETZ

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 12. | Drift and soil | 3 | 6 | 37 | 10 |
| 11. | *Cleveland shale:* Apparently all black, slaty, bituminous shale | 19 | 6 | 34 | 4 |
| 10. | *Chagrin formation:* Blue, thin sandstone | .. | 1 | 14 | 10 |
| 9. | Gray and black shale, alternating | .. | 11 | 14 | 9 |
| 8. | Blue, thin sandstone from 1 to 1¾ in. thick | .. | 1½ ± | 13 | 10 |
| 7. | Gray and black shale, alternating | 2 | 7 | 13 | 8½ |
| 6. | Blue, thin sandstone from 1 to 2 in. thick | .. | 1½ ± | 11 | 1½ |
| 5. | Soft, gray, argillaceous shale with thin layers of black shale. More or less concretionary layers of thin sandstone occur at irregular intervals | 6 | 9½ | 11 | 0 |
| 4. | Blue, laminated sandstone from 2½ to 3½ in. thick | .. | 3 | 4 | 2½ |
| 3. | Gray and black shale | .. | 3 | 3 | 11½ |
| 2. | Blue, thin sandstone from ½ to 2½ in. thick | .. | 1½ ± | 3 | 8½ |
| 1. | Gray and black shale with thin layers of somewhat concretionary sandstone to lake level | 3 | 7 | 3 | 7 |

The 19½ ft. of upper black shale in the above section clearly appear to belong in the Cleveland shale, and the subjacent shales and sandstones the writer refers to the Chagrin.

*Section at western end of Eagle Cliff Village.*—A mile farther to the southeast the following section was measured at the house of Mr. W. T. Hinz, which is the most eastern one in Avon Township; just to the east is the western end of Eagle Cliff Village of Dover Township.

LAKE SHORE SECTION AT THE HOUSE OF W. T. HINZ

| No. | | Thickness Ft. | Thickness In. | Total Thickness Ft. | Total Thickness In. |
|---|---|---|---|---|---|
| 4. | Drift and soil | 4 | .. | 47 | 8 |
| 3. | *Cleveland shale:* Apparently all black, slaty, bituminous shale | 34 | .. | 43 | 8 |
| 2. | *Chagrin formation:* Blue sandstone and arenaceous shale | .. | 2 | 9 | 8 |
| 1. | Soft, blue to gray, argillaceous shale alternating with thin layers of black shale. There are also thin layers of blue sandstone. Lake level | 9 | 6 | 9 | 6 |

It will be noticed that the cliffs increase in height as followed eastward from the Lake Breeze House to Eagle Cliff. The cliff at the Goetz house, one mile northwest of Eagle Cliff, is nearly 38 ft. high and the one just west of Eagle Cliff 47⅔. These higher cliffs also show a greater thickness of the Cleveland shale, as, for example, 34 ft. in the Hinz Cliff, 19½ in the Goetz, and in the low cliffs near Lake Breeze only a few feet at most.

FIG. 7.—Cliff at eastern end of Eagle Cliff Park on shore of Lake Erie. Upper part of cliff Cleveland shale; lower part Chagrin = Huron.

A view of the shore of Lake Erie at the eastern end of Eagle Cliff is shown in Fig. 7, where the upper part of the cliff is composed of Cleveland shale and the lower part of Chagrin = Huron shale.

The cliffs along the lake shore from Eagle Cliff eastward to Rocky River, the banks of this river, the lake shore cliffs in the western part of Cleveland, and many sections on the streams east of Cleveland have recently been described in Bulletin 15, 4th series of the *Geological Survey of Ohio*, to which the reader is referred for a detailed description of these formations in that part of the state.

## CONCLUSIONS

It has been shown in Bulletin 15 of the *Geological Survey of Ohio* that the Cleveland shale in the Cleveland region is underlaid by the Chagrin and overlaid by the Bedford formation. The upper part of the Chagrin formation in the Cuyahoga Valley and to the eastward contains a marine molluscan fauna concerning the age of which there appears to be a general agreement that it represents

FIG. 8.—Cleveland shale at junction of East Branch and West Branch of Rocky River at Olmsted.

the Chemung of southern New York which belongs in the upper Devonian. The basal part of the Bedford formation also contains a marine molluscan fauna which has been found as far west as both sides of the Vermilion River and is also present in central Ohio. The weight of evidence also appears to support the reference of this fauna to the Devonian which has been effectively presented in a recent paper by Dr. Girty.[1]

In Bulletin 15 in connection with the present paper, it is shown

[1] *Annals New York Academy of Sciences*, XXI, 295–319.

how, as the Chagrin formation is followed westward from Rocky River along the lake shore and in the stream valleys, that thin layers of black shale appear in the typical blue and gray shales of the Chagrin. These alternating layers of blue and black shales were found in the lower courses of the Black and Vermilion rivers, while on the Huron River, the typical locality of the Huron shale, it was seen that this formation consists of a certain number of zones of practically pure black shale alternating with those that are composed of generally rather thin zones of blue to gray shale alternating with black shale. The formation has a thickness of over 200 ft. in the Huron River region and the thick zones of black shale contain spherical concretions of variable size. The invertebrate, vertebrate, and plant fossils contained in the Huron shale are of Devonian age according to the opinions of at least most paleontologists who have recently studied them.[1] The Cleveland, composed mainly of black, bituminous shale containing lens-shaped layers with cone-in-cone structure and without spherical concretions, overlies the Chagrin formation in the Cleveland region and on Rocky River, while to the west in other streams or in the cliffs of the lake shore nearly, if not quite, as far as Lake Breeze it overlies the alternating blue to gray and black shales with thin sandstones. The Cleveland shale overlies similar alternating shales in the Black and Vermilion river valleys and the Huron shale in the Norwalk region. The thickness of the Bedford formation is variable in all this region, largely due to the erosion of its upper surface before the deposition of the Berea sandstone, which was perhaps in general greatest in the Norwalk region where frequently all of the formation is wanting and at most only the lower part remains. The Bedford fauna and the disconformity between the Bedford or Ohio shale and Berea formations favors drawing the line of separation between the Devonian and Mississippian at this horizon. It appears clear that the upper black shale crossing this district is the Cleveland, that the Huron shale in general is the western lithologically more or less changed stratigraphic equivalent of the Chagrin formation, and that both the stratigraphic and paleontologic evidence agree in referring it to the Devonian.

[1] For a summary of these opinions see *Geological Survey of Ohio*, Bulletin 15, chap. vi, 509–29.

# *OSTODOLEPIS BREVISPINATUS*, A NEW REPTILE FROM THE PERMIAN OF TEXAS

S. W. WILLISTON
University of Chicago

In the summer of 1909 the writer found, on West Coffee Creek in Willsbarger County, Texas, a series of seven articulated vertebrae and their connected ribs, for the most part concealed in a small block of red sandstone. At the time of their discovery a new genus of reptiles was recognized in the specimen, but only recently has the opportunity for its further examination presented itself. The removal of the concealing matrix has revealed certain unique characters that will justify the description of the well-preserved, though incomplete specimen.

The vertebrae resemble those of *Araeoscelis* more closely than those of any other form hitherto made known from the Permocarboniferous deposits of America. They also seem to resemble those of *Tomicosaurus* Case, so far as their arches are concerned—the centra are unknown in the latter genus—but differ in the presence of stout diapophyses and much greater size. The centra of *Ostodolepis* are as broad as long. The ends, as usual, are deeply and conically concave, with a small perforating foramen. The under side is gently concave longitudinally, broad from side to side, and gently concave in the middle transversely. Just above the sides of the nearly square under surface there is a shallow lateral fossa near the middle. The arch is low and flattened, broad from side to side, though not at all cotylosaurian in character, and has a very small, almost vestigial, tuberculiform spine. The zygapophyses are broad and flat, and their articular surfaces look almost directly upward and downward. On the lower part of the arch on each side, near the front end of the vertebra, there is a rather stout, but short, diapophysis, directed outward and a little downward and backward, with its free end oval in outline and gently cupped. Unlike any centra from Texas hitherto

observed by the writer, those of the present specimen on their free surface show numerous, irregularly placed, minute pits leading into nutrient canals.

The ribs, for the most part, are preserved in position. Each has a rather prominent and stout tubercle lying in apposition with the end of a diapophysis; and the capitulum lies in the intercentral space below the middle of the vertebra, and near the end of the very slender intercentrum. The fractured ends of the ribs show a small central cavity filled with crystals.

The block of matrix, as discovered, showed along its fractured edges, nearly parallel with the under side of the vertebrae, two series of overlapping, slender, bony lines, which were first supposed to be merely imbricated ventral ribs, though the absence of fractured ends was inexplicable. When the lateral surfaces were cleared of matrix these lines were found to be the fractured edges of bony plates. These lines lie along the broken edge of the block in very orderly arrangement, their inner, posterior ends about one millimeter apart; they are directed obliquely forward and outward. Each line measures about eight millimeters in length, and is of about the thickness of writing paper; they lie closely upon each other and are straight. The external, anterior, and very thin margins of these scutes are directed forward, a remarkable arrangement. None of the scutes can be laid bare completely, but the numerous ones seen on the surface below the vertebrae show a width of each approximating its length. The angles are broadly rounded. The outer surface seems to show shallow concentric grooves, possibly corresponding to the free margins of the overlying scutes, of which there are about six. Under a hand lens they show very distinct, slender raised lines, quite concentric with the free margin. In general the scutes resemble the cycloidal scales of bony fishes.

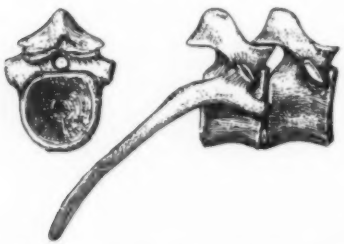

FIG. 1.—*Ostodolepis brevispinatus* Williston. Posterior dorsal vertebrae from the side and in front, with articulated rib. Natural size.

The surface showing these scutes, as exposed on each side, is about an inch and a quarter in width, and must have been originally at least a half-inch wider. The scutes continue quite to the vertebrae, ascending a short distance on their sides, and over the ends of the posteriorly directed ribs. It would seem very probable that, after decomposition of the body had begun, the skin bearing these scutes had slipped down from the ribs and vertebrae till it came nearly in contact on the two sides. No trace of the scutes, however, was found in the matrix over the arches of the vertebrae.

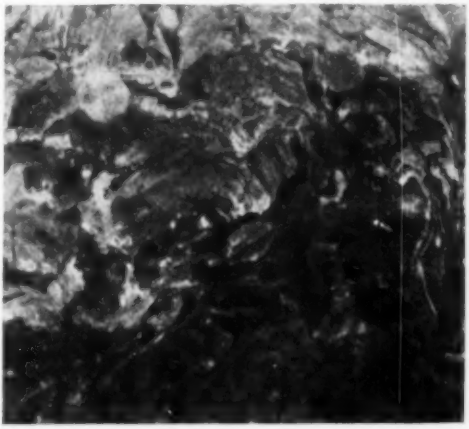

FIG. 2.—*Ostodolepis brevispinatus*. Scutes of right side. Enlarged.

Whether or not these scutes originally covered the whole of the body can not be determined in this specimen, though it is quite evident that they covered the whole under surface of the abdomen as high up as the vertebrae, in the living animal. The vertebrae are evidently from the posterior dorsal region. Such bony scutes, whether they be ventral only or not, are wholly unlike anything that has hitherto been observed among the Permocarboniferous reptiles of America, and very unlike the slender ventral ribs which have been observed in other genera, such as *Labidosaurus*, *Captorhinus*, *Poecilospondylus*, *Varanosaurus*, *Ophiacodon*, etc. In all

these genera these ribs appear to be continuous, directed backward, outward and upward from the median line back of the coracoids, and they are not at all imbricated. In this remarkable specimen they lie everywhere in five or six imbricated layers directed obliquely forward and outward, the thin external edges about one millimeter or a little more apart. Such an arrangement, if they be dermal structures, must certainly have been inconvenient for a crawling creature, unless it were descending a tree! And this leads to the conclusion that these scutes, notwithstanding their close imbrication and fish-like appearance, must have been ossifications in the connective tissue, and overlaid by the skin in life.

The very short spines, the broad and flat zygapophyses and strong rib attachments suggest a slender lizard-like form for the living animal, one probably with long legs and prehensile feet, cursorial or climbing in habit.

The name *Trispondylus* Williston (this Journal, XVIII, 592) is preoccupied; it may be replaced by *Trichasaurus*, nom. nov.

# NOTE ON THE GEOLOGY OF THE ISLE OF PINES, CUBA

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Carnegie Museum, Pittsburg, Pa.

It was the good fortune of the writer to be one of a party constituting an expedition of the Carnegie Museum to the Isle of Pines during the month of May, 1910. While primarily busily engaged in collecting and studying the flora of the island, the writer incidentally noted certain geologic features of the island some of which are erroneously reported in our present literature.

The Isle of Pines is situated about 65 miles south and a little west of Batabano, a small seaport on the south coast of Cuba almost directly south of Havana. The area of the island is approximately 1,200 square miles and it is divided by an east-west swamp into an irregularly oblong northern portion measuring about 30 miles east and west and a narrow southern portion about 40 miles long, east and west, with its western end tapering out and upcurving toward the northwest for a considerable distance beyond the remainder of the island. The general features of the northeastern and central portions of the island are well described by Hayes,[1] who notes that the island "consists essentially of a level plain above which rise numerous isolated ridges. The plain itself consists of three distinct elements: (1) a low coastal fringe, (2) elevated terraces, (3) interior plain."

The writer can add little to Hayes's description of the portion of the island covered by the latter; but the lower valley of the Río de las Nuevas was explored to its mouth in the extreme northwestern point of the island, and it may be added that here the shallow sea is being rapidly reclaimed through the agencies of the mangroves and the alluvial materials washed down by the river. This river is the largest one in the island and for several miles back from its

[1] "Report on a Geological Reconnoissance of Cuba, Made under the Direction of General Leonard Wood, Military Governor, by C. Willard Hayes, T. Wayland Vaughan, and Arthur C. Spencer, Geologists, 1901," *Annual Report* of Brig.-Gen. L. Wood, Military Governor of Cuba, 1901. Vol. I.

mouth the whole surrounding region can be seen to have been rescued from the sea by the united efforts of the river and the mangrove.

The twenty-mile trip from Nueva Gerona to Los Indios, on the western coast of the island, was made by automobile, going south from McKinley across the level and fairly fertile plain constituting the upper drainage basin of the Río de las Nuevas. The ridge forming the divide between this river and the rivers draining toward Los Indios was found to have rather easy slopes, with but little rock exposed, this rock being a quartz-mica schist. Toward Los Indios we soon dropped to a slightly elevated level plain whose surface in places consisted of considerable areas of glistening white angular quartz pebbles and was almost bare of vegetation. As noted by Hayes, there is considerable iron lying about in places, evidently left after the erosion of the soft schist. Much of this surface iron was noted in a trip made from Los Indios to the highest point of La Cañada range about 6 miles west of the town.

The Sierra de la Cañada was supposed by Hayes[1], judging from its topography viewed from a distance, to be of the Gerona Marble; but the ridge is made up of quartz-mica schists, distinctly banded, with a general northeast dip. The southwestern exposure is quite steep and precipitous and probably owes this character to wave-cutting during a past period when the land stood at a different level, as is so clearly shown around the bases of the marble mountains in the northeastern part of the island. The top of the ridge was found to attain a height of 985 feet, by barometer, and access was fairly easy by following up the ravines and along the rather gentle slopes of minor ridges. The whole ridge is covered by a sparse pine and star-palm vegetation wherever the plants can get a foothold. At the base of the steeper side of the ridge is a well-developed talus slope, and from this stretches away immediately the quite level sandy or gravelly plain, pine-covered clear to the coastal fringe. Willis, in his "Index"[2] has unfortunately accepted the erroneous supposition as to the character of the Sierra de la Cañada.

[1] *Op. cit.*, p. 114.

[2] Bailey Willis, "Index to the Stratigraphy of North America," *Professional Paper 71, U.S. Geol. Surv.*, 1912, p. 349.

From Siguanea City the writer, in company with Col. T. J. Keenan and Dr. T. D. Atkinson, made the trip across Siguanea Bay to the peninsula extending out from the southwestern corner of the island. Here the bottom of the bay shallows very gradually out to the low shore and apparently the same general rise continues clear across to the "south coast," a distance of three miles or more. The surface of this part of the peninsula consists of a hard "coral" limestone in the little pockets of which a rich humus soil has collected and which thus supports a rich, broad-leaved vegetation. On the "south coast," at Caleta Grande, the sea was beating against a very rough and jagged coast with a cliff which in many places reaches a height of 80 or 90 feet. A narrow shelf projects out into the sea at a slight depth, bearing numerous projecting jagged rocks, and from this shelf the sea deepens very rapidly to the south. The surface of the coral limestone of this peninsula appears to have about the same general northeast dip as was seen in the Sierra de la Cañada.

# *Reviews*

*Geology.—Reconnaissance of the Jarbidge, Contact and Elk Mountain Mining Districts, Nevada.* By F. C. Schrader. Bull. U.S. Geological Survey No. 497, pp. 162, with maps, sections, and illustrations. 1912.

*Geography.*—The districts are in Elko County in northeastern Nevada near the Idaho state line. They are contained in an east-west rectangular area about 35 miles long by 26 miles wide, the Jarbidge district being in the western part, the Contact district in the eastern part, and the Elk Mountain district in the northern part. Geologically and mineralogically the Elk Mountain district is a small-scale replica of the Contact district.

The area is about 50 miles distant from the Twin Falls Branch of the Oregon Short Line Railroad on the north and from the Southern Pacific Railroad on the south. It lies in the northeastern part of the upland region known as the Nevada Plateau. It is mainly on the southern rim of the Snake River drainage basin, whence it extends across the divide and includes a small part of the adjacent Great Basin on the south. It lies at the general elevation of about 6,000 feet, but it is mostly mountainous and has a vertical range of nearly 6,000 feet and culminates at about 11,000 feet in the Jarbidge Mountains on the west. In the western part the drainage issues northward through the Bruneau River, and in the eastern part easterly, thence northward through the Salmon River, both rivers being main south-side tributaries of the Snake.

*Geology.*—The area is in a region of fundamentally Paleozoic sedimentary rocks seemingly Carboniferous. They consist principally of quartzite, limestone, shale, and slate, folded, faulted, intruded by Cretaceous (?) granodiorite, flooded and capped by Tertiary eruptives, principally rhyolite, and overlain by Tertiary lake beds and Quaternary gravel and alluvium.

In the Jarbidge district the rocks are principally rhyolites. Here the Paleozoic sediments are exposed only on the west. They consist, in ascending order, of quartzite, limestone, and shale aggregating about 3,000 feet (?) in thickness and they dip steeply to the north. The rhyolites are separable into two distinct groups, old rhyolite of Miocene (?) age

and young rhyolite, Pliocene. Each consists of a series of superimposed flows.

The old rhyolite occupies a central area about 8 miles square, has a thickness of nearly 5,000 feet, and is the principal ore-bearing rock. Its flows are heavy, ill defined, and lie nearly horizontal. It is gently folded, faulted, and considerably fissured. It is coarse textured with large phenocrysts of wine-colored quartz and feldspar.

The young rhyolite surrounds the old rhyolite with wide extent. It has a maximum thickness of nearly 2,000 feet. It is non-ore-bearing and but little disturbed. Its flows are relatively thin, well banded, and dip gently outward. It is lithoidal or aphanitic with little or no visible quartz, the silica occurring mainly in the form of tridymite.

The principal rocks of the Contact district are the granodiorite and the Paleozoic sediments which it intrudes. The granodiorite occupies a central elongated quaquaversal east-west batholitic belt 25 miles long by 6 miles wide. Surrounding it in a belt several miles in width succeeds the overlying quaquaversally outward dipping Paleozoic sediments with a known thickness of about 1,600 feet. They are considerably contact metamorphosed by the magmatic intrusion of the granodiorite and both they and the granodiorite are intruded by complementary syenitic, aplitic, lamprophyric, and monzonite dikes. The rhyolite which occurs chiefly peripherally corresponds to the young rhyolite of the Jarbidge district with which it seems to be continuous. The old rhyolite of that district seems to thin and peter out on the western headwaters of the Salmon and does not appear in the Contact district.

The Tertiary lake beds of the area occur chiefly in low places in the Contact district where they have a known thickness of 400 feet. They are mainly gray "sandstone" composed of volcanic tuff which is chiefly pumiceous. In places they are tilted, flexed, and gently folded. They seem to be of Pliocene age and belong to the Humboldt formation.

The Quaternary deposits of the area include in the Jarbidge Mountains, besides recent stream gravels, débris, and wash from the hills, also some glacial accumulations of Pleistocene age.

*Ore deposits.*—The ores were deposited in at least two distinct periods of mineralization, Cretaceous (?) and post-Miocene.

The Cretaceous (?) deposits are chiefly auriferous and argentiferous copper ores. They occur mainly in the Contact district and consist principally of contact metamorphic deposits conforming to the contact zone of the granodiorite with the Paleozoic sedimentaries, and deposits in fissures. The contact metamorphic deposits contain much axinite,

indicating that pneumatolitic action was an important agency in their origin. The fissure deposits are associated with the complementary dikes and contemporaneous or slightly later quartz veins, and include replacement deposits in the wall rock. They occur principally in the granodiorite. The fissures have a steep southerly dip.

The post-Miocene deposits are argentiferous gold ores. They occur in quartz-adularia fissure veins in the old rhyolite in the Jarbidge district. They were discovered late in 1909. The fissures are mostly contained in two main systems which converge downward. Those of the west system dip steeply to the east and those of the east system dip steeply to the west. The gangue is pseudomorphic after calcite and rhyolite and was deposited by ascending thermal solutions that dissolved out and replaced the earlier calcite gangue.

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*Sandstone of the Wisconsin Coast of Lake Superior*. By FREDERIK TURVILLE THWAITES. Bull. No. XXV, Wisconsin Geol. and Nat. Hist. Surv. Pp. 117+viii. Plates XXIII. Madison, 1912.

The stratigraphic relations and geologic age of the red sandstones of the Lake Superior region have long been a subject of discussion arising from the fact that the older sandstones are closely allied to the Keweenawan while the younger beds partake more of the general characteristics of the Cambrian. The older sandstones are characteristically composed of arkose material and the strata are nearly always tilted. The younger group is almost wholly quartz sandstone, and its beds are generally horizontal. Both series, so far as known, are entirely devoid of organic remains. Former investigators recognized that the lower group was a part of the Keweenawan series, but opinions differed as to its relation to the upper; some held that the two were conformable, while others maintained that an unconformity existed and that the upper group probably corresponded to the Cambrian of southern Wisconsin, or its conformable downward extension.

One of the principal results of the present study was the conclusion that the upper quartz sandstone grades conformably downward into red shales and arkose sandstones which possess the same characters as the main body of the recognized Keweenawan sediments. As no conclusive evidence was discovered which tended to indicate that the two groups are unconformable, the facts are believed to warrant the belief that the sandstones form a single essentially conformable series. What has

heretofore been called the "western sandstone" (here called the Bayfield group) is united by Thwaites with the underlying Upper Keweenawan arkose sediments (here called the Oronto group) as one continuous formation. The results of this work show that the contact of the upper, or Bayfield, group with the Middle Keweenawan traps is a fault. At this contact there is some evidence of unconformity, but the author, following Van Hise and Leith, regards it as certain that the folding, faulting, and erosion went on during the deposition of the entire sandstone series, and that the upper beds therefore overlapped with slight unconformity upon the older strata of the same series. The difference in the degree of folding of the two groups of sandstone is correlated with this fact. Both groups were probably deposited subaerially in a basin formed by the bowing of the earlier Keweenawan rocks. They comprise an enormous thickness of sediments, perhaps amounting to as much as 25,000 feet measured in the ordinary way. But the thick series was laid down while deformation of the region was in progress and thus embraces beds which overlap and shingle one another, greatly lessening the total bulk of the formation.

The results of this study, while throwing much light upon the stratigraphic relations in the Lake Superior district, do not in any way determine the relation of the Keweenawan to the Cambrian of the Mississippi Valley. But the fact that the Bayfield group was involved in the profound deformation of the Keweenawan period contrasts it sharply with the slightly disturbed strata of the recognized Cambrian of Wisconsin and Minnesota. The Bayfield group as here interpreted seems, therefore, to be more closely allied to the Keweenawan than to the Cambrian. But this may be apparent rather than actual. For it is not unreasonable to suppose, as Van Hise and Leith have suggested in their *Lake Superior Monograph*, that subaerial sedimentation may have continued within this inland basin nearly or quite up to the time when the advancing Upper Cambrian sea entered the Lake Superior basin. It may therefore be that these sandstones deposited on land may bridge the gap between Proterozoic and Paleozoic. But until the relation of these sandstones to the fossiliferous beds of proven Cambrian age can be determined, the question of the age of the red sandstones still remains a debatable one. It is greatly to be hoped that the author will be able to carry the investigation farther in the endeavor to connect the Lake Superior sandstones with the fossiliferous St. Croix beds lying to the southwest in Minnesota, or with the Cambrian beds lying to the eastward in Michigan.

R. T. C.

*The Sub-Oceanic Physiography of the North Atlantic Ocean.* By PROFESSOR EDWARD HULL. In atlas form, folio size; 11 charts. London: Edward Stanford, 1912.

This, in the opinion of the reviewer, is one of the most important works on oceanography that has ever appeared. It is handsomely published and on such a scale as to show satisfactorily the evidence of the submarine features from the numerous soundings. While many writers have investigated the form and depth of the ocean floor, the nature of the valleys and canyons which cross the continental platform extending beneath the ocean have generally been passed almost unobserved. These omissions on the eastern side of the Atlantic have been filled to a large extent by Professor Hull's investigations, now brought together out of the scientific journals where they appeared, in such a way as to take on their most convincing form. On the European side, Hull shows how the British platform, extending toward Iceland, is deeply indented by the great Spencerian Gulf; how it is crossed by the Irish Sea river, the English Channel river, and other valleys; how the edge of the platform is indented by short embayments such as characterize the border of plateaus high above tide. Similar features appear about the Bay of Biscay where the canyon of Adour is one of the most remarkable. Like features appear also in the canyon of the Tagus and in others that lie off Portugal. Like phenomena are also shown to occur in the Mediterranean. Such also is the great submarine canyon of the Congo to which a separate chapter is devoted.

The analogous features on the western border of the Atlantic and in the West Indies had previously been investigated by Spencer, who contributes a chapter to Hull's book.

Concerning Spencer's original work Professor Hull speaks in very laudatory terms but in this generous tribute to a coworker it should be recognized that this line of inquiry was far from fully deployed until Hull had directed attention to the significant features that occur on the eastern side of the Atlantic and Nansen had published his Memoir touching upon the same subject. Spencer's chapter in Hull's monograph describes some of the most important features of the American side of the Atlantic in narrative form and this supplements and renders more comprehensive the work of Hull in Europe.

Thus the leading data relative to the submerged river-like valleys and canyons on the border of the continents facing the North Atlantic are assembled in convenient and instructive form.

J. W. SPENCER

*Practical Field Geology.* By J. H. FARRELL. New York: McGraw-Hill Book Co., 1912. Pp. 273+xi; figs. 66; tables 4. $2.50.

The title of this handbook is in a sense misleading. Instead of being an exposition of approved methods with practical pointers and helpful short cuts for the use of the general geologist in the field, the word practical is here construed as synonymous with mining, and the book is avowedly limited to a treatment of the field methods employed by mining geologists, engineers, and prospectors. Within the field of mining its scope is further limited by the omission of coal and iron from consideration. And in value coal and iron are the greatest of our mining products.

But within its own chosen field the book can be recommended as a useful guide. In the first five chapters the methods of topographic mapping and some of the simpler phases and problems of geologic mapping are well described and presented so as to be available for use by those who have not had the advantages of elaborate training along geological lines. Then come very readable and instructive chapters on the interpretation of geologic data, general suggestions for geologic work, geological measurements, application of descriptive geometry to mining problems, application of geological theory, rock classification, geological prospecting, and prospecting by drilling. These discussions should be of value to those entering the field of economic geology without specialized training in that line.

Following the main part of the book is a guide to the "sight recognition" of 120 common or important minerals, by A. J. Moses.

R. T. C.

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*The Coal Fields of King County.* By GEORGE WATKINS EVANS. Bull. No. 3, Washington Geol. Surv. Pp. 247; figs. 59; pls. 23. Olympia, 1912.

Washington is the only state on the Pacific coast which produces coal in any quantity and most of this comes from the region between Puget Sound and the main range of the Cascades, principally from King and Pierce counties. The coal beds of these two counties belong to the Puget formation whose age has been determined as Eocene. In character this coal ranges from lignitic bituminous in the less disturbed western part of King County to a bituminous coal in the eastern portion where crustal movements and igneous activity have been more severe. It is a coal that is suited to a great many purposes, though it is not the

equal of some of the high-grade eastern coals, or some of the coal from the Alaskan fields. The careful studies which have been devoted to the geological and commercial problems connected with the King County coal fields are well set forth in this bulletin.

R. T. C.

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*Geology and Ore-Deposits of the Nizina District, Alaska.* By FRED W. MOFFIT and STEPHEN R. CAPPS. Bull. 448, U.S. Geol. Survey. Pp. 108; pls. 12; figs. 11. Washington, D.C., 1912.

The Nizina district is located about eighty miles north of Behring glacier between parallels 61° 12′ and 61° 37′ north latitude and meridians 142° 22′ and 143° west longitude, and embraces about three hundred square miles. The sedimentary rocks are Triassic and Jurassic with some Quaternary deposits and rest upon greenstone of probable Triassic age. Deformation and erosion followed Triassic sedimentation with exposure of the underlying greenstone, after which Jurassic sediments accumulated to a thickness of 7,000 feet. Younger rocks may possibly have been present but if so have been removed. The Jurassic rocks are deformed and cut by great quantities of quartz diorite porphyry in the form of sills and dikes. All the rocks are faulted. Most of the Quaternary deposits are related to glaciation.

Gold is the only metal at present produced on a commercial basis but the copper will be important when means of transporting it to the coast are developed. The gold is in the form of placers some of which are related to glacial deposits though others are not. The copper occurs as chalcocite and bornite with small amounts of native metal in the amygdaloidal form. The origin of the copper deposits is discussed briefly, with full recognition of the speculative nature of the chemical reactions.

E. A. S.

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*The Late Glacial and Post-glacial Uplift of the Michigan Basins. Earthquakes in Michigan.* By WILLIAM HERBERT HOBBS. Mich. Geol. and Biol. Surv. Pub. 5, Geol. Series 3. Pp. 87; pls. 4; figs. 53.

This is a bulletin which is largely intended to present a phase of geology in a popular way. The author has preceded his discussion of the uplift by a series of notes and drawings of various features that are useful in interpreting the history of the basins. These include illustrations of present sinking and rising shore lines, sea cliffs, wave-built terraces,

abandoned shores, bars, barriers, etc. The departure of the shore line from horizontality is used for the determination of the amount and direction of tilting.

Reference is made to the prophecy of Gilbert as to the future reversal of the drainage of the St. Lawrence basin but a modification is offered, based upon a study of the hinge lines crossing Lake St. Clair, and upon the fact that no submergence has been noted near Chicago. The author believes that there are no processes now in operation which tend to reverse the St. Lawrence drainage and so bring about the predicted future discharge through the former Chicago outlet.

The hinge lines of tilting have migrated northeastward following glacial retreat, so that the present southernmost line lies north of the Port Huron isobase.

The pamphlet concerning Michigan earthquakes is largely historical.

E. A. S.

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*Journal of the Washington Academy of Sciences.* Vol. II, January–June, 1912. Washington, D.C.

The separate numbers contain advance notices and brief summaries of articles to appear in various scientific periodicals. These are of marked clearness and value because they are, for the most part, prepared by the authors themselves. Occasional complete papers are contributed, notably those by Nutting on the ether, and by Brooks on applied geology. The proceedings of the local scientific societies are also reported and the journal affords a good medium of thought-exchange for the large number of progressive scientists that are centered in the capitol city.

E. A. S.

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*Triassic Fishes of Connecticut.* By CHARLES R. EASTMAN. Bull. 18. State Geol. and Nat. Hist. Survey. Pp. 75; pl. 11; figs. 8.

Paleontology should be regarded as an extension of human history and one of its great contributions is the expansion of the principles that seem to govern organic and social evolution.

The view that Triassic deposits of eastern America were formed in tidal estuaries that were brackish or nearly fresh is replaced by the conception that they include torrential fans from neighboring mountains, fluvial and lacustrine deposits on the lowlands, and probably some

estuarine sediments. Accumulations of wind-blown material no doubt took place on the land. Judgment based on paleobotanical evidence has previously correlated the Triassic system with the European Keuper, but the occurrence of *Ptycholepis Marshi* (Newberry) in accompaniment with *Semionotus*, *Catopterus*, and the Crossopterygian genus *Diplurus* has led to the assignment of the Newark to a horizon that corresponds in a general way to the interval between the Muschelkalk and the Lower Keuper of European marine Trias. The author has discussed the significance of the fauna but has not recognized the generally accepted classification of the geological time-scale.

E. A. S.

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*Geology and Ore Deposits of the Index Mining District.* By CHARLES E. WEAVER. Bull. 7, Wash. State Geol. Survey. Pp. 93; pls. 7.

A brief discussion of the physical history of the region is given with the general geology. The oldest rocks are provisionally assigned to the Carboniferous, but, like most of the older rocks of the region, they are highly metamorphosed. Much of the geological record is obscure. Some good mine maps add to the clearness of the report.

E. A. S.

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*Geology and Ore Deposits of the Meyers Mining District, and Geology and Ore Deposits of the Oroville-Nighthawk Mining District.* By JOSEPH B. UMPLEBY. Bull. 5, Wash. State Geol. Survey. Pp. 107; figs. 5; pls. 3.

A reconnaissance report on the general geology and ore deposits of these areas; brief description of the various mining properties are included; unfortunately no index map accompanies the bulletin.

E. A. S.

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—Merrill, G. P. On the Supposed Origin of the Moldavites and Like Sporadic Glasses from Various Sources. [No. 1833, from the Proceedings of the United States National Museum, Vol. XL, pp. 481–86, with Plates 61–62. Published May 31, 1911. Washington.]

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—PHALEN, W. C. Preliminary Report of the Coal Resources of the Pikeville Special Quadrangle of Eastern Tennessee. [Tennessee Geological Survey. The Resources of Tennessee, Vol. I, No. 4. Nashville, October, 1911.]

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